Instruments

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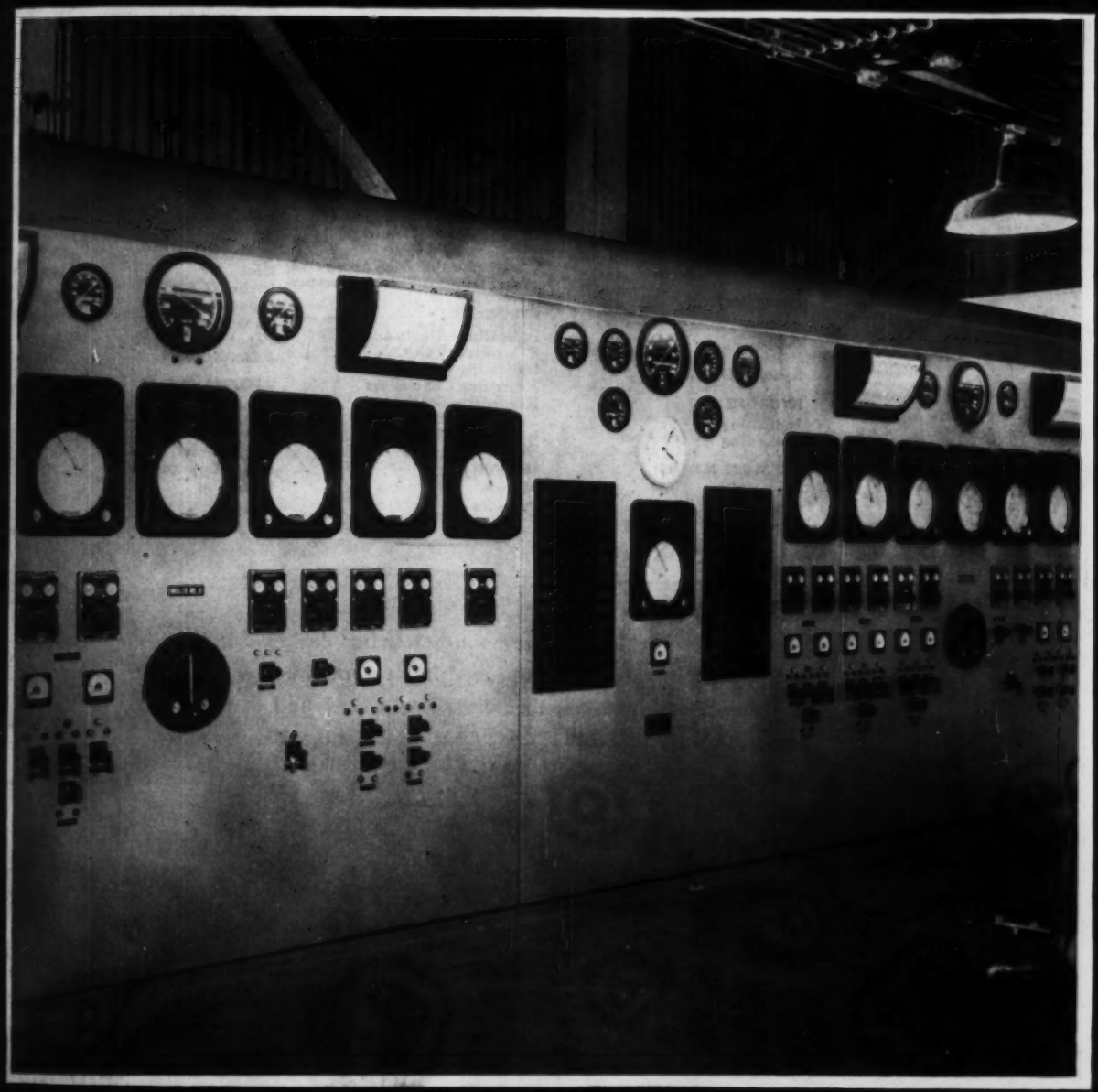

TAG Instruments

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Recording Controllers
Recorders—Single and Multiple Point

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Motion
Pressure
Temperature
Vacuum

RECORDER CONTROLLERS
Humidity
Hydrogen Ion
Pressure
Temperature
Vacuum

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Indicating Controllers
Recorder Controllers
Recorders—Single and Multiple Point

THERMOMETERS
ASTM
Chemical
Dial
Etched Stem
Industrial
Laboratory
Paper Scale
Recording

VACUUM GAGES
Mercurial

VALVES
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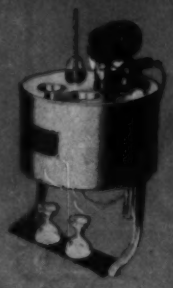
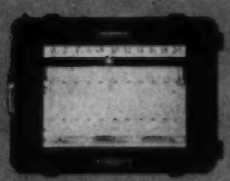
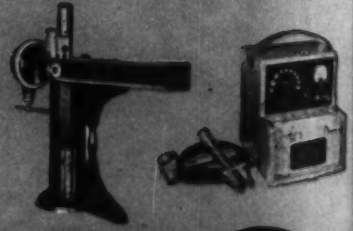
Regulating



Whether the need is for instrumentation to be "designed-in" at the planning stage, or improved instruments for present equipment or processes, the answer will be found in the complete Tag line listed above. Check this list against your instrument requirements, and write to us for complete descriptive literature and prices.





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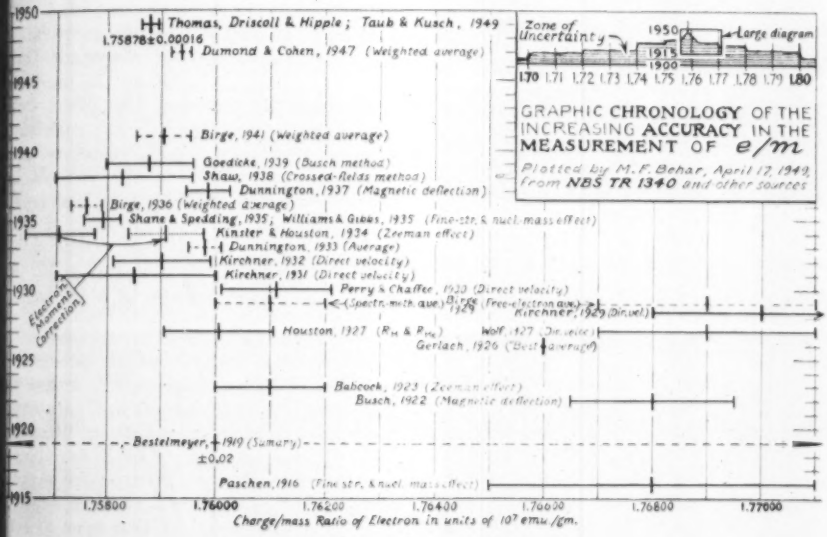
Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Proficient Priests *of* Precision Promote Practical Progress

IN a press conference devoid of fanfare, the National Bureau of Standards announced on March 28th that a team of its scientists had determined two important physical constants with unprecedented accuracy. These are: (1) the absolute value of the magnetic moment of the proton and (2) the value of the charge-to-mass ratio of the electron.


Thomas, Driscoll & Hipple; Taub & Kusch, 1949
1.75878±0.00016
Dumond & Cohen, 1947 (Weighted average)
Birge, 1941 (Weighted average)
Goedicke, 1939 (Busch method)
Shaw, 1938 (Crossed-fields method)
Dunnington, 1937 (Magnetic deflection)
Birge, 1936 (Weighted average)
Shane & Spedding, 1935; Williams & Gibbs, 1935 (Fine-str. & nucl. mass effect)
Kinster & Houston, 1934 (Zeeman effect)
Dunnington, 1933 (Average)
Kirchner, 1932 (Direct velocity)
Kirchner, 1931 (Direct velocity)
Perry & Chaffee, 1930 (Direct velocity)
Houston, 1927
Wolf, 1927
Gerlach, 1926
Babcock, 1923 (Zeeman effect)
Busch, 1922 (Magnetic deflection)
Bestelmeyer, 1919 (Sumary)
±0.02
Paschen, 1916 (Fine str. & nucl. mass effect)
Zone of Uncertainty
Large diagram
GRAPHIC CHRONOLOGY OF THE INCREASING ACCURACY IN THE MEASUREMENT OF e/m
Plotted by M. F. Behar, April 17, 1949 from NBS TR 1340 and other sources
Charge/mass Ratio of Electron in units of 10⁷ emu/gm.

On that occasion, Bureau Director Condon allowed himself to be quoted as declaring that "this basic and far-reaching work of H. A. Thomas, R. L. Driscoll and J. A. Hipple is a most important contribution to modern physics." Hundreds of NBS workers continually make important contributions to science and industry and this has been the Bureau's mission for nearly half a century; but we think this was the first time that a Director uttered such praise of individual NBS workers for the press and radio. Likewise marking the occasion as exceptional was the length of the explanatory statements and the number of photographs and diagrams made available to the press. From this matter we prepared (exclusively for *Instruments* readers) the account on pages 430-432. From an NBS Technical Report and other sources (especially Doctors Birge and Tranathan) we drew the historical graph herewith, in the upper right-hand portion of which we have arbitrarily drawn a thin straight line extending upward into the future—meaning a confident prediction that the value of e/m is known for evermore with hair-line accuracy!

Significance.—The conservative NBS writers mentioned only the purely scientific importance, refrained from predicting any engineering or industrial consequences (the headline on page 430 is ours, not theirs). However, one can foresee refinements in devices that use free electrons (hundreds of different commercial tubes) and in instruments and machines (servos, etc.) that use magnetic fields. Chemical industries, too, will benefit through new or improved devices (such as mass spectrographs) for automatically and continuously analyzing products being processed.

Millikan.—This is the fortieth anniversary of the isolation and "weighing" of single electrons. It was in 1909 that Millikan reported his first series of oil-drop experiments, which later won him the Nobel Prize. There probably will be a fitting celebration later this year.

Columbia.—Nor must one overlook the timely work of Doctors Taub and Kusch at Columbia University: it was their recent re-determination of the "nuclear g-factor" for hydrogen nuclei which was combined with the results of the NBS work to yield the new precise value of e/m.

I-C Curve Revision

THAT old workhorse of industrial temperature measurements, the iron-Constantan thermocouple, has seldom been used for high-precision work. Reason: lack of a Standard accepted by all makers and users. Therefore, the following announcement will interest users:

522 Fifth Avenue,
New York 18, N. Y.
March 30, 1949

To the Editor of *Instruments*:

The Recorder-Controller Section of Scientific Apparatus Makers of America has undertaken, through the Section's Thermocouple Calibration Curve Committee, a joint investigation with the National Bureau of Standards into certain aspects of the iron-constantan calibration curve. . . . The purpose of the investigation is explained in the following quotations from the Committee's minutes:

"At the October 1, 1948 meeting of the Recorder-Controller Section Thermocouple Curve Committee, it was agreed that the 1913 (L&N) iron-constantan curve should be adopted as a S.A.M.A. Tentative Standard over the range 32 to 1400 F. The recommendations of the Committee were approved by the Recorder-Controller Section S.A.M.A. Engineering Executives' Group and subsequently the Committee was empowered to spend up to $1,000 on a joint investigation with the Bureau of Standards, the objectives of the investigation being as follows:

"(a) Extension of the curve to cover the range from −300 F. to 1800 F.

"(b) To make such minor corrections in the '1913' Iron-Constantan curve as may seem desirable as a result of the investigation.

"(c) To convert the curve to absolute values and to incorporate corrections resulting from pending changes to be made in the International Temperature Scale."

HAMPTON M. AULD,
Executive Secretary.

Crying Need of Accuracy

MUCH of what you read about "measurements" of radioactivity by medical men is a lot of hogwash. For example the "strength" of radioactive iodine is known only roughly: the spread of values reported by 150 laboratories is six to one! Fortunately, the NBS is stepping into this picture.

An Easily Assembled Console *for* Rapid Testing *of* Electrical Indicating Instruments

By FRANK D. WEAVER, Electrical Instruments Section, National Bureau of Standards, Washington, D. C.

I. INTRODUCTION

TO speed the testing of electrical instruments, new methods have been designed and new circuits developed. All of the physical components are commercially available, so that a description of the circuits, arrangement of equipment and methods of use may interest *Instruments* readers in industries and institutions where periodic testing is a necessity.

Instruments used for many applications do not require the precise and more time-consuming tests than can be made in a high-precision laboratory. It is largely because of the time that can be saved in adequate semi-precise testing that this description has been prepared. In the design of this quick-check console, special attention was given to simplicity, convenience and compactness of arrangement.

II. GENERAL DESCRIPTION

In order to design a test table that would facilitate the rapid checking of electrical instruments, it was necessary to select a method of testing that would be simple and convenient and one that would give results of the desired accuracy. Past experience had shown that these requirements can be most effectively met by comparing the pointer indications of the instrument under test with the pointer indications of a similar instrument of equal or higher accuracy for which the scale corrections are known. Using the comparison method as the basis of design, circuits were developed to cover the testing of the types and ranges of electrical indicating instruments ordinarily used in a laboratory. This method requires adequate sources of power and a convenient switching and control arrangement that provides both coarse and fine control in adjusting the voltage and current to insure the maximum ease and speed in testing. Since this method relies ultimately on the reference instrument for its accuracy, a discussion of the testing and use of reference instruments is given in Section IV.

The accompanying wiring diagram and photographs, Figs. 1, 2 and 3, indicate the arrangement of equipment, which in our case was conveniently arranged to make use of a stationary laboratory table. The layout has been under consideration for several years and the actual construction embodies experience gained in a number of rearrangements and changes in components made during this period to give maximum compactness, flexibility and convenience.

The usual a-c. power supply (Fig. 1) serves as a source for both alternating current and voltage and for direct voltage. The direct-current source is a storage battery capable of supplying a current of 50 amperes. The voltage and current controls indicated in Fig. 1 and shown in Figs. 2 and 3 have been conveniently located to permit easy operation of the coarse and fine adjustments of the alternating and direct currents and voltages required for testing. The proper selection of ranges and controls gives adjustments fine enough for increments of pointer indication of 0.05 division or less to be easily obtained within the usual ranges of alternating- and direct-current ammeters and voltmeters. The convenient sources and controls provided are adequate to cover (1) direct and alternating voltages from 0.1 to 300 volts, (2) alternating current from 0.01 to 100 amperes, and (3) direct current from 0.01 to 50 amperes.

The regular a-c. power supply to the building suffers from fluctuations in voltage too large to allow the precision testing of instruments directly on this supply. It was found that, by using a voltage stabilizer, the effects of such supply-voltage variations could be reduced to a point where they would not be troublesome. Thus both power for alternating-voltage and -current testing, and power for direct voltage in this test table, are supplied through the stabilizer which is connected to the regular 60-cycle a-c. supply. A magnetic-type stabilizer with a built-in filter is indicated at the upper left-hand side of Fig. 1 by the block VS. The output wave-form of the stabilizer has a total harmonic distortion of less than 5 percent and is therefore quite satisfactory for use as a source in testing. Electronic stabilizers with even less distortion (1 to 2 percent over a wide range of input voltage) are now commercially available.

In assembling the components of the console, precautions were taken to avoid stray magnetic-field errors in the instruments undergoing tests. Thus conductors, which may occasionally carry large currents, are located at a safe distance from the area on the table where the instruments are placed for testing. Variacs, transformers, and rheostats are likewise located at a correspondingly safe distance. The reference instrument and the instrument under test are connected to the appropriate binding posts on the panel. Thus leakage and capacitance currents that occur in the wiring behind the panel do not influence the accuracy of test results obtained by the use of this set-up.

III. DETAILED DESCRIPTION

A. Direct-current Arrangement

The source of current, 0.01 to 50 amperes, for direct-current measurements, is a group of storage cells (see Fig. 1) arranged as a 2-, 4-, or 8-volt supply. The coarse control for current ranges from 1 to 50 amperes is obtained by a set of four "tubular" rheostats (A, Figs. 1 and 2) having screw-driven brushes. They are placed in a compartment to the left of the observer and beneath the table top. These rheostats, by means of a switching arrangement, may be used singly, or in parallel in groups of two or more. Fine control at the higher ranges is obtained by three circular rheostats (B, Figs. 1, 2 and 3) mounted on the panelboard and arranged to permit connection in parallel with the coarse control rheostats. One of these circular rheostats is used as a voltage divider and the other two serve as adjustable series resistors. These three panelboard resistors are suitable for controlling the current in the lower range from 0.01 to 1 ampere. A millivoltmeter with shunts of the following current ranges: 0.015, 0.03, 0.075, 0.15, 0.3, 0.75, 1.5, 3, 7.5, 15, 30 and 75 amperes, serves as a reference ammeter.

B. Direct-voltage Arrangement

Direct voltage (0.1 to 300 volts) is supplied by a single-phase full-wave rectifier. By incorporating a filter in this d-c. power supply, ripple is reduced to about 0.2 percent. This power supply with its filter is shown at C in Figs. 1 and 3. A discussion of this type of circuit is given by Herbert J. Reich[2].

A two-pole four-position transmitter switch with Isolantite insulation (G, Figs. 1, 2 and 3) makes it possible to supply three different input voltages to two Type 200B Variacs (D and E, Figs. 1, 2 and 3). Three positions on the switch are connected to three tap points on a transformer shunted across the output of the voltage stabilizer (H, Fig. 1). Thus, depending on the position of the voltage-range switch, the coarse- and medium-control Variacs may be supplied with 10, 60 or 120 volts. The output of the medium-control Variac supplies the primary of a 110/2.5-volt step-down transformer (F, Fig. 1). The output of this transformer is used in series with the output of the coarse-control Variac to permit small adjustable increments in voltage supplied to the rectifier, and thus fine adjustment of the output direct voltage is obtained. The three positions on the switch and the coarse- and medium-control Variacs then make it possible to

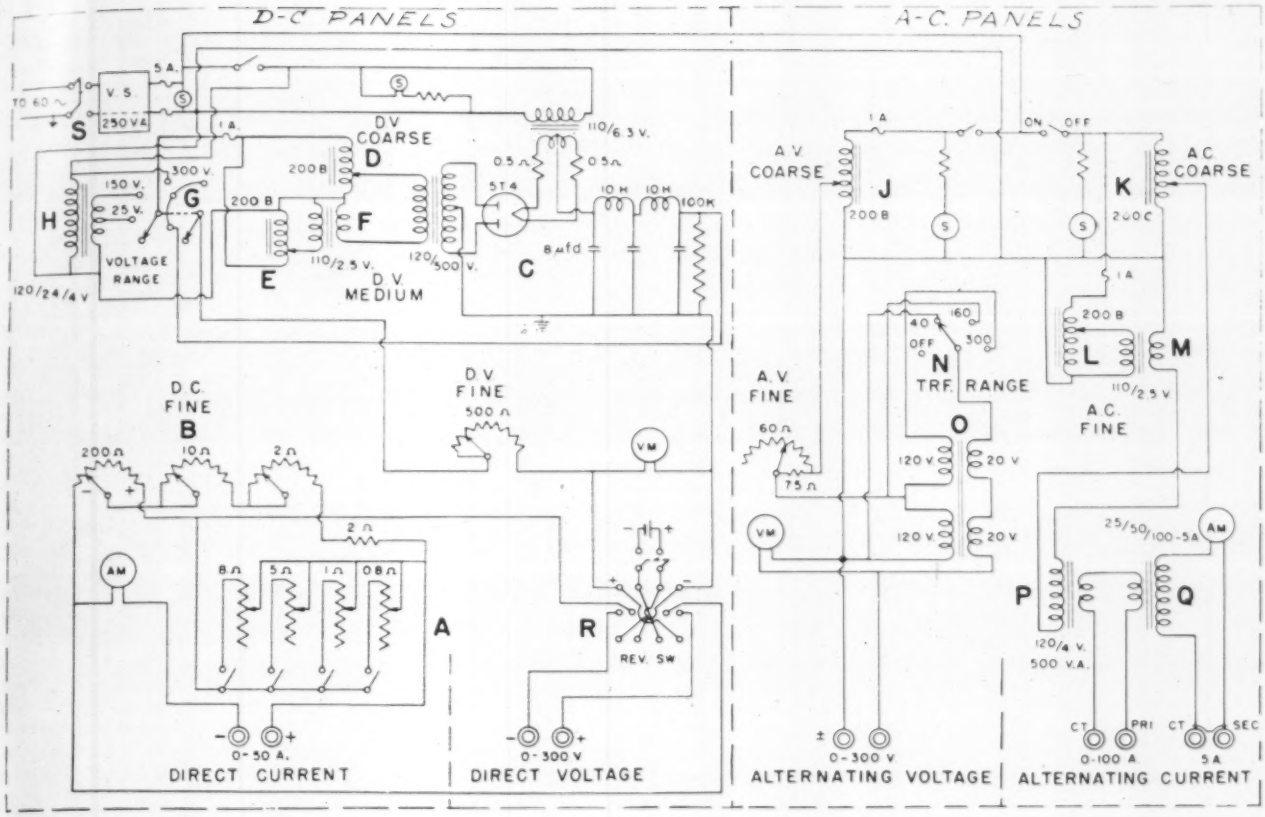


Fig. 1. Wiring Diagram

obtain adjustable voltage at the "DIRECT VOLTAGE" terminals of 0-25, 0-150 or 0-300 volts. The maximum permissible current drain from the power supply is 200 milliamperes. A rough indication of the voltage at the voltage terminals is given by a panelboard voltmeter (VM, Fig. 1). A red warning lamp in the tube circuit shows when this circuit is energized. A single multi-range d-c. voltmeter with the following ranges: 1.5, 3, 7.5, 15, 30, 75, 150, and 300 volts, serves as a satisfactory reference instrument.

C. Alternating-current Arrangement

The stabilizer output is also used as the source for alternating-current testing for ranges from 0.01 to 100 amperes. A Variac (Type 200C) (K, Figs. 1, 2 and 3) is used for coarse control of the test current. Its output side is connected in series with the 2.5-volt winding of a 110/2.5-volt step-down transformer (M, Figs. 1 and 3) to feed a 500-va 120/4-volt "supply" transformer (P, Figs. 1 and 3), of which the four-volt winding provides the test currents up to 100 amperes. A second Variac (Type 200 B) (L, Figs. 1, 2 and 3) is used for fine adjustments of the test currents by arranging its output to supply the 110/2.5-volt transformer (M, Figs. 1 and 3). In order to facilitate measurements, a current transformer (Q, Figs. 1 and 3) with 20/25/40/50/80/100 to 5-ampere ranges is also built into the set-up and connected in series with the secondary of the 500-va. transformer (P, Figs. 1 and 3).

In testing a-c. ammeters, one of the following three circuit arrangements is used, depending on the range of the ammeter: (1) For ranges greater than 15 amperes, the ammeter to be tested is connected to the terminals marked "CT PRI," and a 5-ampere reference ammeter is connected to the terminals marked "CT SEC," with the primary coils of the current transformer connected for the appropriate range. (2) For ranges from 1 to 15 amperes, the ammeter under test and a reference instrument of the same range are connected in series to the terminals marked "CT PRI," the secondary of the current transformer (Q, Figs. 1 and 3) being shorted by a copper link at the terminals marked "CT SEC." (3) A current transformer having ranges of 0.05/0.075/0.1/0.15/0.25-0.5/0.75/1/1.5 to 2.5 amperes conveniently covers current ranges below 1 ampere. When this transformer is used the ammeter to be tested and the primary coil of the transformer are connected in series to the "ALTERNATING VOLTAGE" terminals with the current transformer coils connected for the proper range and the range switch (N, Figs. 1, 2 and 3) set on the "40 V" position. A 2.5-ampere ammeter is connected to the 2.5-ampere winding of this low-range current transformer. Since this transformer is portable and is used only occasionally, it is not a permanent part of the equipment and is not shown in the wiring diagram. If a low-range current transformer is not used, then ammeters of the following ranges, either in single or multi-range reference instruments, are desirable: 0.015, 0.03, 0.05, 0.1, 0.15, 0.3, 0.5, 0.75, 1, 2.5, 5 and 10 amperes. If, however, a low-range current transformer is provided, ammeters having ranges of 2.5, 5 and 10 amperes will effectively cover most of the ranges normally required in testing.

D. Alternating-voltage Arrangement

The voltage stabilizer serves also as the source for alternating-voltage testing. The control of alternating voltage, 0.1 to 300 volts, is obtained by means of a Variac (Type 200B) in combination with a 60-ohm circular rheostat shunted with a 75-ohm fixed resistor, the adjustable rheostat being used for fine control (J, Figs. 1, 2 and 3). Three ranges of voltage, 0-40, 0-160 and 0-300 volts, are obtained with the aid of a range switch (N, Figs. 1, 2 and 3), from a 240/120 to 40/20 volt transformer, (O, Figs. 1 and 3). A single-pole four-position switch serves as a range switch and is used to connect the windings of this transformer so that the three ranges mentioned above are obtainable. The coarse and fine controls provide an adjustable input voltage of from 0 to 130 volts on one coil of the primary. A panelboard voltmeter gives a rough indication of the voltage at the terminals and a red warning lamp indicates that the power-supply switch has been closed. Voltmeters of the following ranges serve as suitable reference instruments: 1, 5, 10, 20, 30, 60, 75, 150 and 300 volts.

It may be more convenient to use a

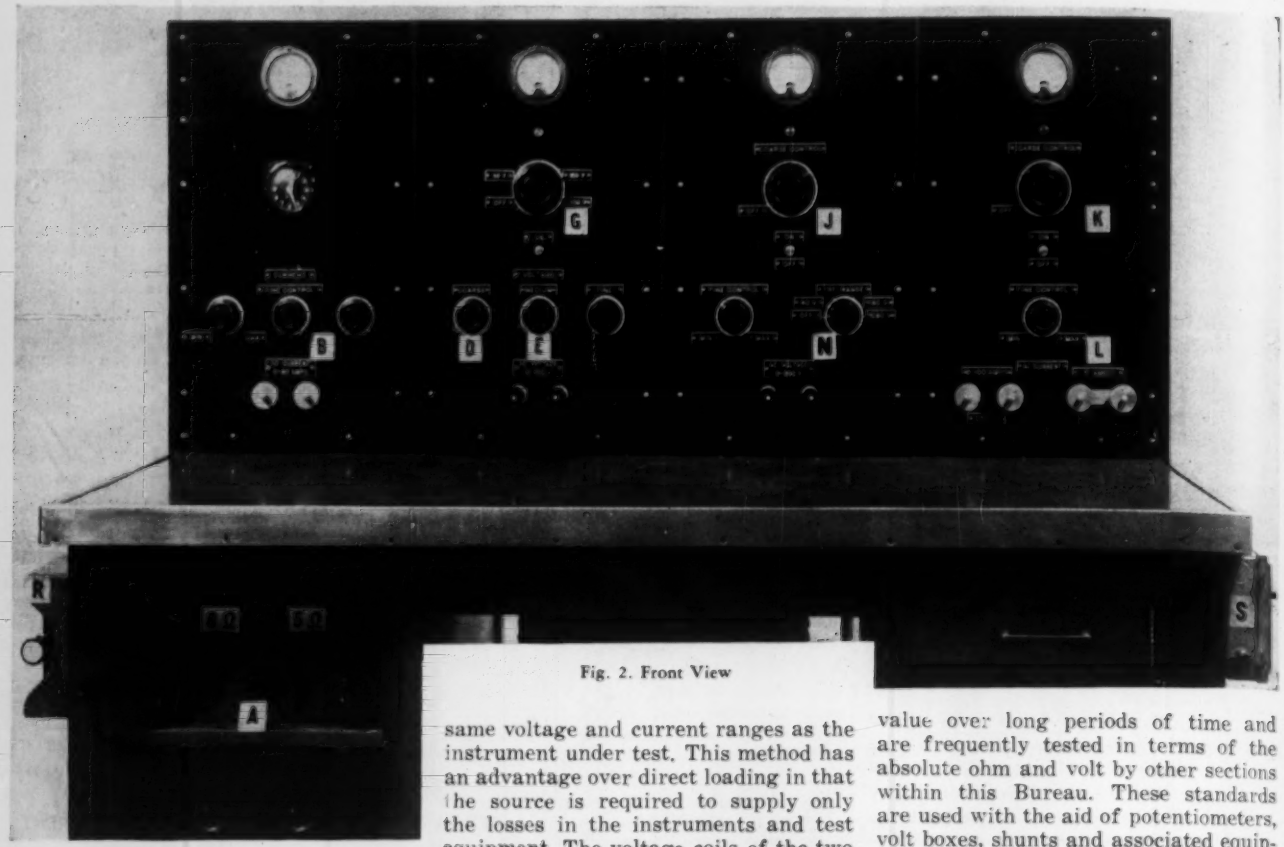


Fig. 2. Front View

special three-winding 1.5/3/7.5/15/30/-60-to-150-volt "potential" transformer in addition to a voltmeter having ranges of 75, 150 and 300 volts for the testing of a-c. voltmeters with ranges from 0.5 to 300 volts. In testing with this combination the low-range voltmeter is connected to the proper low-voltage winding of the transformer and its readings are compared with those of a 75-volt or 150-volt reference instrument connected to the high-voltage secondary winding. The voltage for any given indication of the instrument under test is computed by multiplying the corrected reading of the reference instrument by the corrected value of transformer ratio for the transformer connections used.

E. Tests on Reversed Direct Current

This console serves as the source of current and voltage for testing ammeters, voltmeters and wattmeters of the electrodynamic type on reversed direct current. In such a test a reading is taken for current flowing in one direction and is averaged with a second reading for current flowing in the opposite direction, thereby minimizing residual or stray magnetic effects. The direction of current flow is reversed after each reading by means of the reversing switch (R, Figs. 1 and 2). In general this method gives more accurate results than a straight a-c. test.

Phantom loading is employed in testing wattmeters on reversed direct current. Separate sources of voltage serve to energize the voltage and current circuits of the instrument and a reference instrument is used that has about the same voltage and current ranges as the instrument under test. This method has an advantage over direct loading in that the source is required to supply only the losses in the instruments and test equipment. The voltage coils of the two instruments are connected in parallel to the terminals marked "DIRECT VOLTAGE," and the current coils are connected in series to the terminals marked "DIRECT CURRENT." Precautions should be taken to prevent overloading either the voltage or current coils. The panelboard indicators are helpful in avoiding excessive currents during switching and adjusting. The precaution should be taken to connect the voltage terminal marked ± of each wattmeter to the voltage terminal marked ± on the panelboard. Likewise the current terminals of the wattmeters are connected in series such that the ± terminal of one is connected directly to the ± current terminal on the panelboard. In order to avoid the errors caused by electrostatic effects resulting from differences in potential of the two circuits, the ± voltage terminal of one wattmeter should be connected to its ± current terminal by a length of fuse wire or by a voltmeter.

IV. TESTING AND USE OF REFERENCE INSTRUMENTS

Basically, the method employed in our quick-check testing consists of a comparison of readings of the instrument under test with those of a high-grade instrument for which the corrections are known. In our work the corrections for these reference instruments are accurately determined periodically (about once every year) in a high-precision laboratory. The tests in the high-precision laboratory are based upon a group of resistance standards and unsaturated standard cells which show remarkably small drifts in value over long periods of time and are frequently tested in terms of the absolute ohm and volt by other sections within this Bureau. These standards are used with the aid of potentiometers, volt boxes, shunts and associated equipment in direct-current testing of voltmeters, ammeters and wattmeters. Because no standard of alternating voltage corresponding to the standard cell exists, laboratory-type "transfer" instruments of the electrodynamic type are used in the testing of alternating current instruments. A detailed discussion of "transfer" instruments is contained in papers by F. K. Harris,[5] John H. Park and Arthur B. Lewis,[8] and Francis B. Silsbee.[10]

The reference instruments, periodically tested in the high-precision laboratory, were selected to insure the performance and reliability needed for quick-check testing of other instruments. In the selection of instruments, such factors as accuracy, pointer width, use of anti-parallax mirrors, scale length, scale marking, temperature compensation, zero shift, and magnetic and electrostatic shielding were taken into consideration. This set of instruments is reserved for use only in this test table. Such a restriction tends to increase the sustained reliability of the instruments and makes it feasible to lengthen the time between tests of the reference instruments.

Ordinarily a permanent-magnet moving-coil ammeter or voltmeter is used as a reference instrument to test another permanent-magnet moving coil ammeter or voltmeter on direct current. A permanent-magnet moving-coil or electrodynamic instrument is used to test another of electrodynamic type on reversed direct current, and an electrodynamic instrument to test those of other types on alternating current.

For tests on a given range of an in-

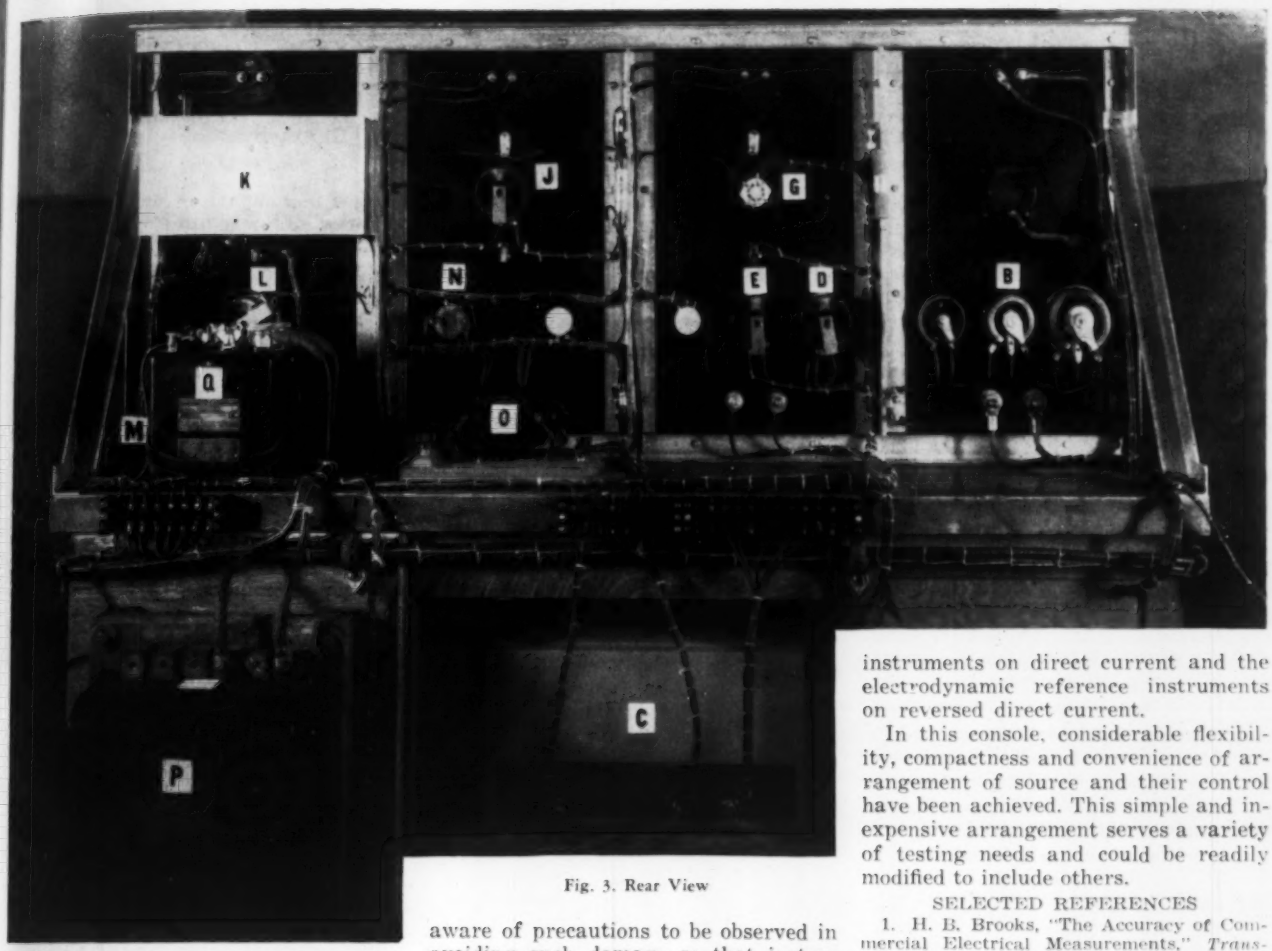


Fig. 3. Rear View

strument, the points on the scale are compared with a reference instrument having the same nominal range and with the same number of scale divisions as the instrument under test, or with a greater number. It is advisable, insofar as possible, to use only about the upper half of the scale of a given range of the reference instrument for comparison tests. It is desirable to have standards with 102 scale divisions to test instruments with 100 scale divisions, and standards with 152 scale divisions to test instruments with 150 scale divisions. Instruments with two such extra divisions on the scale are not regularly available but can be supplied by the manufacturer on special order. They are quite convenient for use in testing ordinary instruments at the top scale point.

It is considered best practice to use two observers in making tests, one to set the pointer of the instrument under test and the other to read the reference instrument. One serves as a check on the other and thus mistakes may be avoided. Ordinarily the instrument is tested at five or more of the cardinal points on the scale. A hand lens is a useful aid in reading the instrument scale.

Many parts of an electrical instrument, such as pivots, jewels, shunts, springs and coils, are subject to irreparable damage as a result of improper care and rough handling. It is imperative that instrument users become aware of precautions to be observed in avoiding such damage so that instruments may give the years of useful service that the manufacturer built into them.

V. CONCLUSION

This description covers the equipment at present used as a distribution and control board for the rapid testing of the wide range of electrical instruments usually found in an instrument laboratory. The instruments under test are compared with instruments, reserved for use as standards, for which the errors are known. These reference instruments are periodically tested in equipments capable of high precision. This implies that others planning to use such a distribution and control board for comparing one instrument with another would need equipment for checking the accuracy of their reference instruments. If standardization facilities are not at hand, it might be desirable to provide, instead of a number of d-c. reference instruments, a portable multiple-range shunt for direct-current measurements and a volt box for direct-voltage measurements used in conjunction with a Brooks deflection potentiometer. The accessories and this quick-reading potentiometer would then be used in place of the less accurate d-c. reference instruments. However, if the use of reference instruments for checking was found to be more convenient because of a large amount of testing, the potentiometer and its accessories could be used to test the d-c. reference instruments on direct current and the electrodynamic reference instruments on reversed direct current.

In this console, considerable flexibility, compactness and convenience of arrangement of source and their control have been achieved. This simple and inexpensive arrangement serves a variety of testing needs and could be readily modified to include others.

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Flight Testing *of* Automatic Cooling Controls

By E. P. HETZEL, Chief Flight Test Engineer, Northrop Aircraft, Inc., Hawthorne, Calif.

DURING the evolution of the modern military airplane, the necessity for providing automatic controls to perform certain functions has become apparent. This need is most evident in connection with power plants of the familiar reciprocating-engine type. As the number of engines installed per airplane and the power output per engine have both increased, the provision of automatic control has become a must.

EDITOR'S NOTE.—This highly-informative article holds wide interest beyond aviation. It not only shows how *autographic* instruments aid rapid analysis of phenomena occurring during a test, but describes a *two-part, widely-applicable test procedure* that can be repeated accurately.—M. F. Behar.

Initial efforts along these lines were made in connection with the single-seater fighter airplane whose pilot, during combat, was sufficiently burdened with his problems in lining up the plane as a gun platform without having to worry about continually setting various cooling controls. The advent of the large multi-engined bomber (4 or 6 engines) made it necessary to provide a Flight Engineer whose primary duty was the supervision of the power plants, but this additional crew member was immediately overloaded. In addition to watching the functioning of auxiliary power units, electrical systems, hydraulic systems, etc., he might have to watch these *basic* power-plant indications:

Engine speed	6
Manifold pressure	6
Engine oil pressure	6
Carburetor air temp.	6
Oil temperature	6
Engine cylinder temp.	6

Of these items, engine speed and manifold pressure must be adjusted to obtain the desired power, but both of them are usually maintained automatically when once set. Engine oil pressure is automatically regulated.

The regulation of the other three items —carburetor air, oil, cylinder head temperatures—may be either manual or automatic. The optimum use of the Flight Engineer's talents can be obtained if he is relieved of the duty of operating the eighteen switches associated with these three items. We will discuss techniques used in determining the proper settings of automatic controls used for these three functions.

The following items are among those which have been requested by various procuring agencies:

1. Accuracy of temperature control
2. Effect of automatic control of cooling shutters or flap on trim of airplane
3. Effect of automatic control of cooling shutters or flap on performance of airplane (range, rate-of-climb, etc.)

Consideration of these items leads to the conclusion that the first item, accuracy of temperature control, is the only one which either can or needs to be determined.

With respect to the second item—trim changes—it hardly seems fair to associate undesirable trim changes with automatic control since any trim changes which occur during satisfactory automatic control would have occurred in the same manner if manual control had been used. Large-scale instability might, of course, cause excessive trim changes, but such instability could not be permitted for a number of other reasons. With a properly operating control, a large flap or shutter movement will be required only when a large change in heat rejection (change in engine power) or a large change in available cooling medium (change in airspeed) occurs. These changes in power or airspeed ordinarily cause trim changes in comparison with which the cooling flap or shutter trim changes are definitely secondary.

With respect to the third item, performance improvement, it has always appeared to our personnel that an accurate automatic control would be able to maintain temperatures more nearly at the desired operating level than any human operator could hope to do—with consequent decrease in drag and improvement in performance. Therefore, performance comparison with and without automatic control hardly seems subject to accurate engineering tests.

That leaves just one item to test—accuracy of temperature control. In the case considered here, the reciprocating engine power plant is the heat source; and ram air, controlled by a shutter or exit flaps, is the cooling medium.

The instrumentation required to determine sufficient design data to permit a complete correlated analysis would be

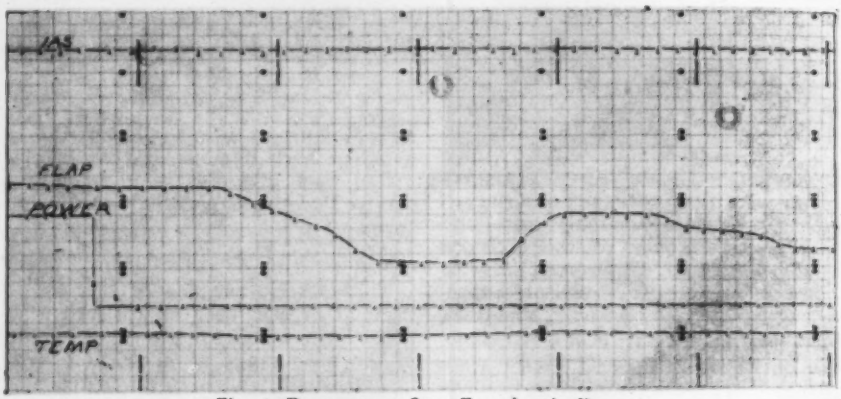

Fig. 1. Response to Step Function in Power.

EDITOR'S NOTE.—This illustration and the three others are about one-fourth actual size. Each shows a section eighteen inches long of the original Brown strip chart, representing a flight test of six minutes' duration. On each of the originals, the four different records have been made more visible by Northrop Aircraft personnel, who drew short lines in ink between the plus-mark points made by the instrument's printing mechanism. (Otherwise it would have been difficult for readers to make out all four records in each illustration.) Users of multi-point recorders know that this is permissible as a general rule and that it should be done with extreme caution where there are more-or-less sharp "corners," especially when a human being has tried to apply a step function, i.e., a supposedly instantaneous change, to an engine or to an airplane. In such cases, drawing two straight lines at an angle (like a letter L) where a series of automatically-recorded points gives the appearance of a smooth curve, may provoke discussions.

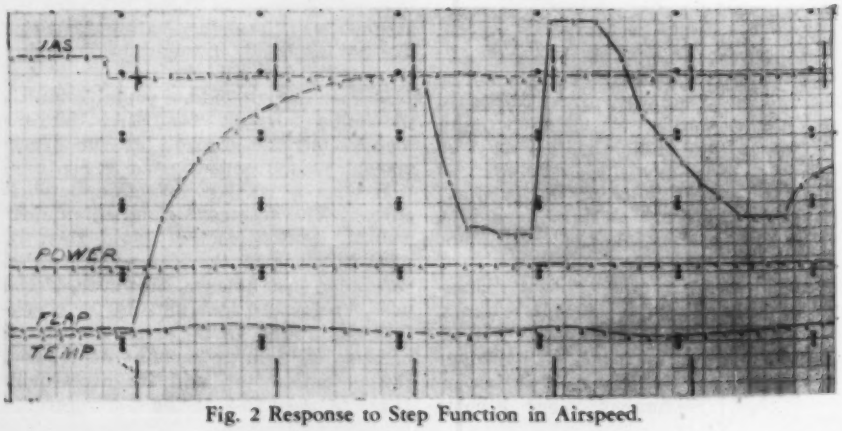

Fig. 2 Response to Step Function in Airspeed.

much more extensive than that required to conduct operational tests on a prototype control. Since we are primarily concerned with operational tests, only the instrumentation required for this purpose will be considered:

1. Time.—Any suitable timepiece, including recording instrument's constant-speed chart drive;
2. Engine power.—Selsyn transmitter;
3. Control point temperature.—Thermocouple;
4. Cooling flap or shutter position.—Selsyn transmitter;
5. Airspeed (IAS).—Statham pressure transmitter.

A convenient method of correlating and analyzing the data is to record the last four items on the continuous strip chart of a Brown multi-point automatic temperature recorder, Model 161632, the constant-speed paper drive providing the time scale. This recording system permits quick inspection of the data during or after the flights. Typical records taken during various types of tests are reproduced herewith.

TEST PROCEDURES

The testing of an automatic temperature control is usually divided into two phases: During the first phase, step function changes in cooling potential or heat rejection are applied, followed by steady-state conditions. In the second phase, the cooling potential and heat rejection are varied concurrently and cyclically to determine the amount of temperature overshoot during violent transient conditions. The piloting technique may be described as follows:

1. Step function. At an appropriate altitude a combination of engine power and airspeed is determined, such that the cooling flaps or shutter will stabilize at a slightly-open position when level flight is maintained. When stabilized temperatures and cooling flap position have been obtained, the power is abruptly increased (while the airspeed is held constant) to some value which requires a stabilized cooling flap position somewhat greater than the initial setting. This airspeed and power are maintained until a stabilized cooling flap position is obtained—then the power is abruptly reduced to its initial value, again holding the airspeed constant. This procedure, if properly carried out, will keep the pilot quite busy as each power change must be as rapid as possible, yet must be coordinated with the operation of some drag-producing device (varying power on the second engine of a twin-engine airplane or varying landing-flap position on a single-engine airplane) in order to maintain altitude and airspeed. In order to compare the control operation during tests in which different sensitivity or rate settings are used, it is imperative that the power settings be accurate and that the airspeed be maintained exactly (airspeed variations of more than plus or minus 2 mph may change the cooling potential sufficiently to cause apparent instability of control if extremely sensitive settings are being used). A record of a typical test of this type is shown in Fig. 1.

A similar procedure is used in applying a step function in cooling potential (airspeed) at constant power. Again the piloting technique is difficult as it is necessary to alter the drag of the airplane as the airspeed is changed so that constant altitude will be maintained. A typical record of such a test is shown in Fig. 2.

2. Cyclic variations. From any initial condition, the power is abruptly increased to maximum while the airspeed is reduced to a value just above stalling. As the temperature rises, the cooling flap will start to open. At the correct moment (to be described later) the power is abruptly reduced to idle and the nose pitched down to pick up airspeed as rapidly as possible. The temperature will continue to rise and the cooling flap continue to open for a short time after the power is reduced. The correct moment to have reduced the power is such that the cooling flap does not reach the full open position before starting to close. Soon after the flap starts toward the closed position (in some cases even before it starts closing) will be the correct moment to pull the nose up, reducing the airspeed while returning the power to its maximum value. It may require three or four cycles for the pilot to get the "feel" of the exact moment to initiate power and airspeed changes so that the cooling flap will not reach full travel during any part of the cycle. This test determines the amount of temperature overshoot during transient conditions. Fig. 3 shows a typical run with cyclic airspeed variations at constant power.

The tests described above are normally conducted at two altitudes—first near sea level and later near the maximum operational altitude for the particular airplane. As a final check, functioning of the automatic control is recorded during a takeoff followed by an immediate climb at maximum power at optimum airspeed to a normal operational altitude and subsequent cruising power level flight at this altitude. Data obtained during a takeoff and rated power climb are shown in Fig. 4.

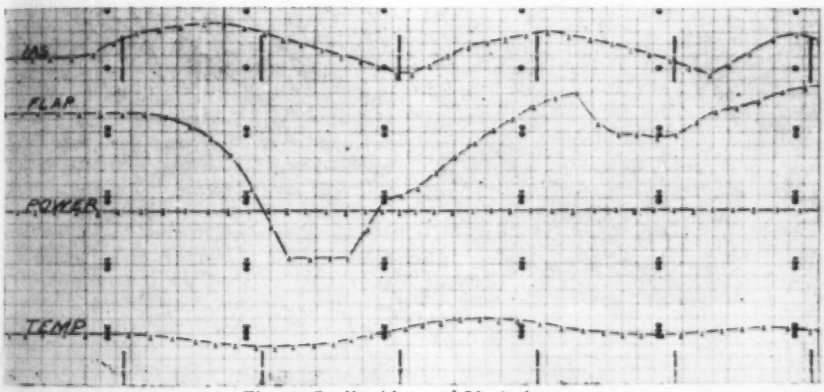

Fig. 3. Cyclic Airspeed Variations.

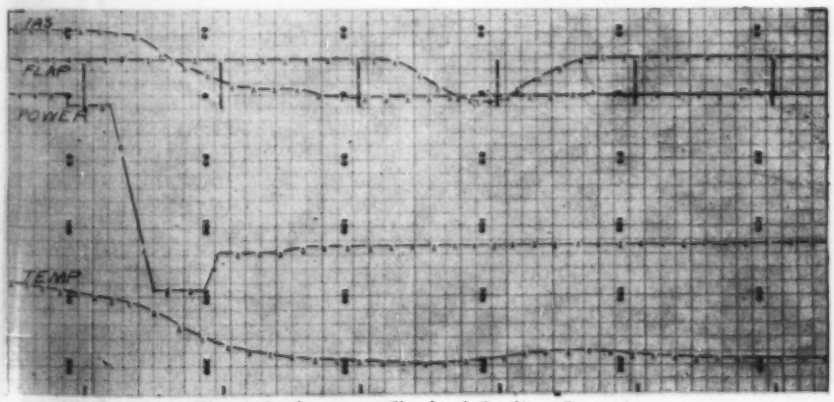

Fig. 4. Performance Check of Cooling Control.

CONCLUSION

This testing technique may be applied to units controlling any cooling medium—air, oil, water, Prestone, etc.—and to any type of control (off-on, proportional, floating). It will usually be found that the critical stability conditions are encountered at high levels of both heat rejection (high power) and cooling potential (high airspeed). Satisfactory completion of the series of tests outlined above—complemented by a reasonable amount of service testing to eliminate service malfunctions—will assure that the automatic control will perform its design function and thereby permit the pilot or flight engineer to utilize his abilities most efficiently.

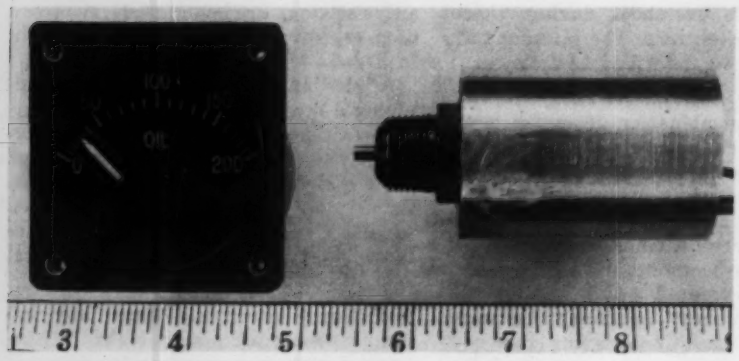

Fig. 1. Pressure transmitter and indicator.

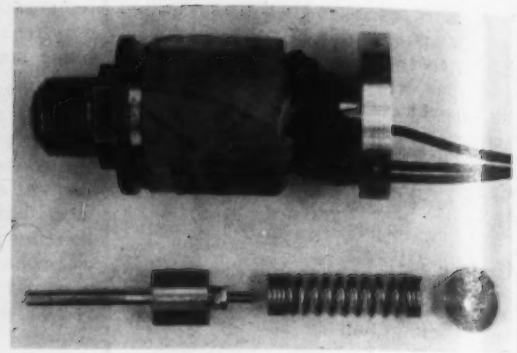

Fig. 2. Pressure transmitter disassembled.

An A-c. System *of* Remote Indication *and its* Application *to the* Measurement *of* Fluid Pressure *and* Flow*

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Fig. 3. Transmitter mounted on engine.

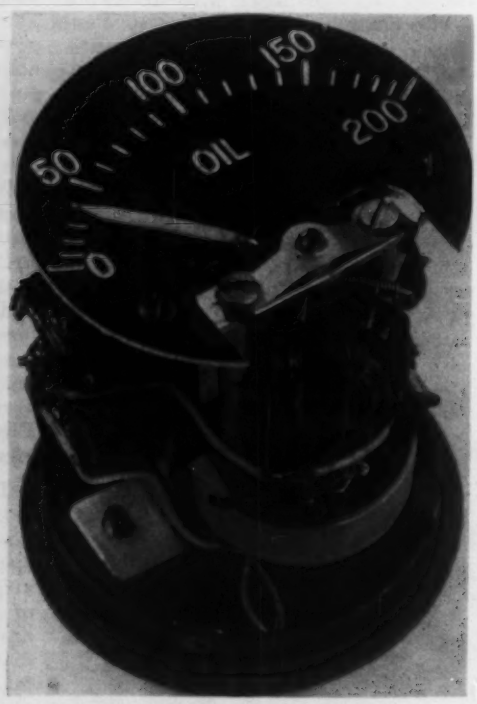

Fig. 4. Indicator with case removed.

Fig. 5. Indicator partly disassembled.

A MOVING-VANE indicator in circuit with a two-coil transmitter form a system of remote indication relatively free from errors due to variations in ambient temperature, supply voltage, and supply frequency. The transmitter is simple and should withstand severe vibration and extreme temperatures. The electrical elements of the transmitter are completely isolated from the mechanical components so that measurements in the presence of corrosive or explosive fluids may be made with safety. Applications are presented in which the transmitter measures oil pressure in the crankcase of a gasoline engine and the flowmeter measures fuel flow. This system of remote indication has been developed for use in aircraft, but its potentialities for industrial applications will become evident. The experimental models were designed to operate from 400-cycle aircraft power sources; larger components would be required for 60-cycle operation.

The transmitter contains a movable core within a set of coils which are connected so that their magnetic fields are in opposition. The core is displaced by a force derived from the fluid under measurement, and its position is established when the fluid force is balanced against the opposing force of a coil spring. Three conductors serve to transmit two electrical signals from the transmitter to the indicator.

The indicator contains a vane (Fig. 7) of highly permeable magnetic material located within a set of crossed coils. The transmitter voltages are applied to the indicator coils through a bridge circuit, and their resultant magnetic field positions the vane which is fastened to the pointer shaft. The indicator contains resistors for sensitivity and end-scale adjustments, and suitable assemblies for damping and pointer zero return.

*This article is a condensed version of the thesis submitted by the author in partial fulfillment of the requirements for the degree of M.S. in E.E. at the University of Pennsylvania and was prepared at the Naval Air Experimental Station, U. S. Navy Yard, Philadelphia, Pa., in 1945. This work was supported by the Bureau of Aeronautics, Navy Department, Washington, D. C.

Measurement of Fluid Pressure

One application of this system is to the electrical remote indication of aircraft engine oil pressure. There is a need for an aircraft remote-reading oil-pressure gage with a transmitting element suitable for direct mounting on the aircraft engine. The coagulation, at low temperatures, of the engine oil in the line from the crankcase to the transmitter of any of the remote-indicating oil-pressure gages in present use makes these gages inoperative during a part of the engine warm-up period. The lack of oil pressure indication at this time frequently leads to serious engine damage which would not otherwise occur. The device herein described is capable of offering a satisfactory solution to this problem.

Models of both transmitter* and indicator** for measuring oil pressure are shown in Fig. 1. Fig. 2 shows the same transmitter partly disassembled, Fig. 3 shows another model of the transmitter mounted on a test-cell engine oil-pump.

The portion of the transmitter (Fig. 2) that responds to fluid pressure is a piston free to slide within a closely-fitting cylinder. The piston is rigidly connected to a magnetic core which it positions against the restraining force of a coil spring. The piston and spring are enclosed within a non-magnetic steel tube which supports two identical coils separated by a magnetic washer. A vented plug threaded into the open end of the tube serves to adjust the initial spring load and to limit the travel of the core.

The indicator, shown in Figs. 4, 5, 6, and 7, is a moving-vane crossed-coil instrument. The coils are supported by a plastic form within which the vane is free to rotate. The vane (of magnetic material) is "threaded" onto the pointer shaft in the manner shown in Figs. 6 and 7. The shaft also carries a permanent magnet which, in the assembled instrument, rotates within a copper housing which provides eddy-current damping of the moving assembly. A cup of magnetic material fits over the copper housing and shields the magnet from the earth's field.

When the indicator coils are energized, their magnetic fields combine to produce a resultant field with which the vane aligns itself and thereby positions the pointer. Since the position of the pointer depends on the ratio of the coil currents, this instrument is relatively free from errors due to variations in supply voltage and hence may be classified as an "A-c. Ratiometer."

The indicator is connected to the pressure transmitter as shown in the circuit diagram, Fig. 8. Resistors A, B, and C are contained within the indicator case. With the dial calibrated in oil pressure, as in Fig. 1, and the transmitter properly applied to the source of fluid pressure, this system provides a means of remotely indicating the measured quantity.

*U. S. Patent No. 2417097
**U. S. Patent No. 2419612

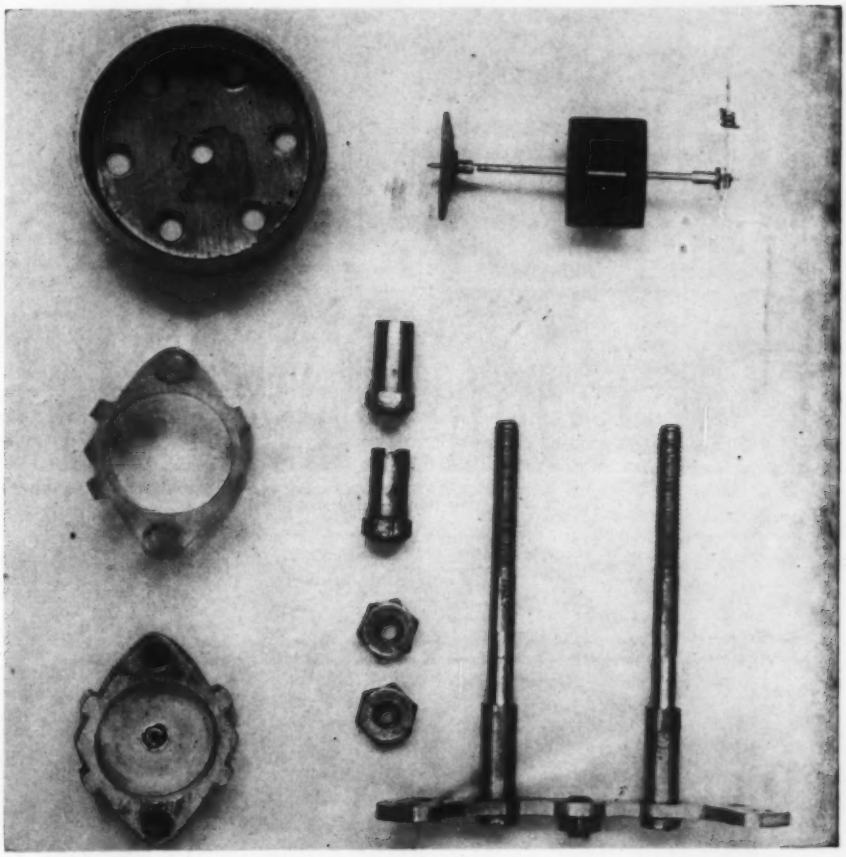

Fig. 6. Indicator parts.

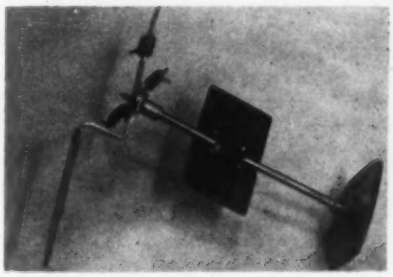

Fig. 7. Indicator moving assembly.

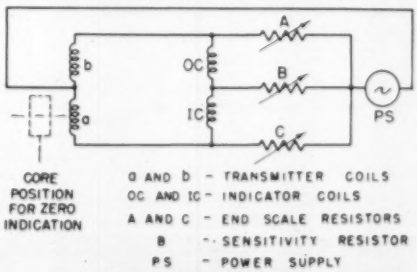

Fig. 8. Circuit diagram.

Measurement of Fluid Flow

Another application of this system is to the remote indication of fluid rate-of-flow through tubing such as the fuel supply line of an aircraft engine. One model of the flowmeter transmitter* is shown in Figs. 9, 10, 11, and 12. Fig. 13 shows a sectional drawing of this model plus a few minor changes in design.

Electromagnetically, the operation of the flowmeter transmitter is identical to that of the pressure transmitter. The difference lies in the hydraulic system used to derive the force necessary to displace the core. In this application, the magnetic core is tubular, and is designed to support firmly an orifice plate that restricts the flow of fluid. The restriction sets up a pressure differential across the orifice plate that positions the core against the restraining

* U. S. Patent Application No. 594131

Fig. 9. Flowmeter transmitter.

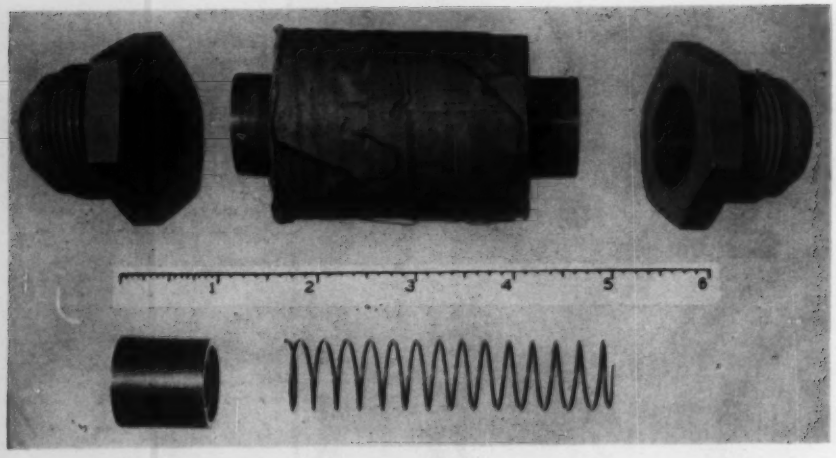

Fig. 10. Flowmeter transmitter disassembled.

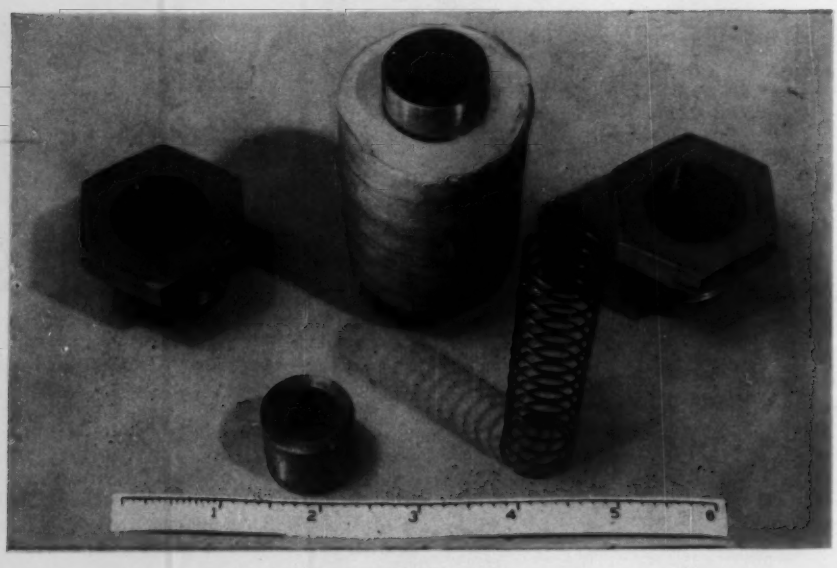

Fig. 11. Principal parts of flow-rate transmitter.

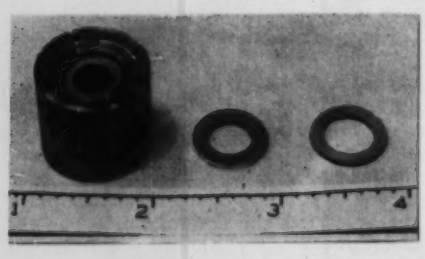

Fig. 12. Core and orifice plates.

force of a coil spring. Fig. 12 shows the core with one orifice plate installed, and two replacement plates that are used for different ranges of rate-of-flow. As in the case of the pressure transmitter, the core slides within a non-magnetic steel tube which supports the electrical windings.

In operation, fluid passes through the flowmeter and sets up a force to displace the core against the action of the spring. The currents in the electrical windings have a unique value for each core position. Hence, the ratio of indicator-coil currents is a function of core position so that when suitably calibrated, the complete system provides an accurate indication of fluid rate-of-flow.

Test Results

The pressure gage was tested to determine the inherent inaccuracies of the electrical system. With the indicator at room temperature (25 degrees C.) the transmitter temperature was varied from minus 55 deg. C. to plus 70 deg. C. The maximum error in indication was approximately plus-or-minus two percent of full scale. When the supply voltage was varied from 80 to 120 volts, the maximum errors were plus 0.3 percent and minus zero percent of full scale. Variations in supply frequency of plus-or-minus 5 percent produced maximum errors in indication of plus-or-minus 1 percent of full scale.

Summary

An a-c. system of remote indication has been presented with specific applications to the measurement of fluid pressure and flow. It should be noted that the system provides a remote indication of displacement and therefore may be applied to any device or machine that can supply the necessary force to position the core of the transmitter.

In the transmitters described, the complete isolation of the fluid chambers from the electrical system permits the application of these units to measurements of corrosive or inflammable fluids. Furthermore, the inherent ruggedness and relative freedom from temperature errors ideally suits them for use under conditions of severe vibration and extremes in temperature.

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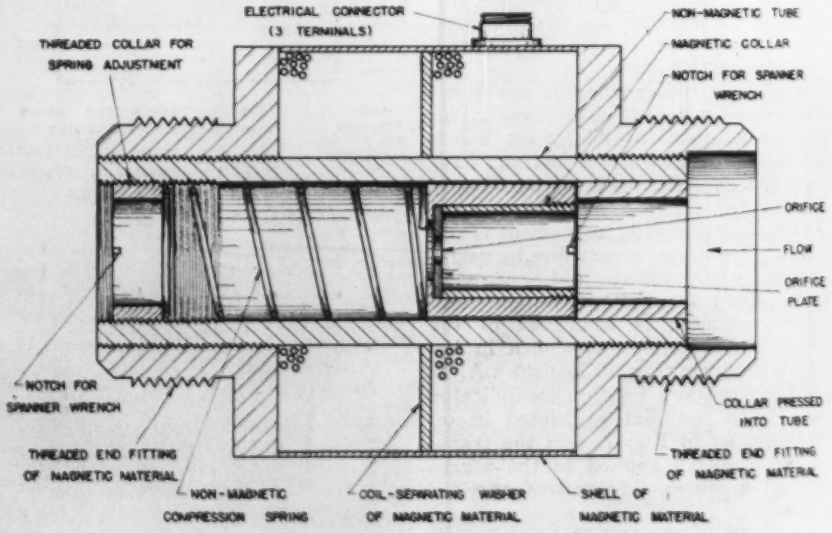

Fig. 13. Longitudinal section of flow-rate transmitter.

New Method *of* Expanding *the* Scale *of a* Magnetic Oscillograph

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IT is often difficult to observe the transient behavior of voltage signals, especially where the distance between maximum and minimum points of the voltage-wave envelope is only a few percent of the steady-state value of a large voltage signal. By expanding the scale a magnetic oscillograph, a portion of the envelope is expanded a number of times, thus presenting a much clearer picture of the amplitude variations during the transient period.

A number of methods have been designed to accomplish this purpose but the circuit shown in Fig. 1 is believed to have the advantage of simplicity. It is a suppression circuit and the increase in scale is adjustable by varying the galvanometer sensitivity control.

The principal components of the circuit (Fig. 1) are a full-wave high-vacuum rectifying tube, a half-wave gas rectifying tube, a voltage regulating tube, and a Variac. The input voltage signal is across points 1 and 10 and can be adjusted by the Variac so as to suppress the portion of the incoming signal below the bias point.

The Type 2050 tube rectifies the alternating voltage, eliminating the lower half of the voltage wave altogether. The control grid at point 3 is connected over resistor R to the plate. The screen grid is connected to the cathode. Therefore, across terminals 4 and 5 there is a rectified voltage. However, this half-wave rectified voltage is biased at a certain point by a 105-volt voltage-regulating tube between points 5 and 10, and the voltage wave is suppressed completely below this point. In order to maintain this bias point, a glow must be initiated and sustained in the tube. This can be accomplished by stepping up the 115-volts a.c. to 550 volts, and then rectifying the full-wave by means of a Type 5V4-G tube. Rheostat P is the d-c. adjustment. The current needed is about five milliamperes for steady state in order that constant glow can be sustained in the Type VR105 tube. The 25000-ohm limiting resistor prevents the current in the d-c. circuit from exceeding a certain value. Capacitor C acts merely as a filter.

The two oscillograms in Fig. 2 show the advantage of the circuit. An output voltage signal of 218 volts rms. from a 300-kva. 400-cycle alternator was used. The oscillograms show the wave-forms when a 450-ampere inductive load (0.55 power factor) was turned off. The films were taken with a General Electric PM-12 two-element magnetic oscillograph, a calibration chart of which is shown in Fig. 3. The galvanometer sensitivity control was set at 0.5 volt per millimeter, the oscillograph being calibrated at the setting. If desired, a greater amplification could have been obtained by increasing the sensitivity. However, in this case, the first peak of oscillation of the voltage-wave envelope would have been off-scale.

From Fig. 3 it can be seen that the relationship between volts and deflection in millimeters is linear above 92 volts rms. and of a magnitude of one volt rms. per millimeter, or 1.41 volts peak per millimeter deflection. The Variac was adjusted to 118 volts rms. across the output terminals, this being the most convenient deflection. Since the input voltage was 218 volts rms., the ratio of input to output was 218 over 118, or 1.84. Multiplying the Variac ratio of 1.84 by the calibration constant of 1.41 volts per millimeter gives 2.6 volts peak per millimeter. Since the first peak after turning off the load is 22.5 mm. above the steady-state load value, and since there are 2.6 volts peak per millimeter, the first peak must be 58.5 peak volts above the steady-state load peak value. From the oscillograms, it is evident that the regulated generator voltage reaches a value of 0.5 percent of its final sustained value within a time as little as 290 milliseconds.

From Fig. 2-A, the deflection of the first peak is 3.5 millimeters. The galvanometer setting was 16.4 peak volts per millimeter, so that the magnitude of the peak is 57.5 volts which equals, approximately, the figure in the preceding paragraph. The amplification thus can be obtained by dividing the ratio between volts and deflection without the circuit by the value with the circuit. By doing this, we obtain a gain of 16.4 over 2.6, or 6.3.

Therefore we are able to read, in this particular case, the oscillation of the voltage-wave envelope 6.3 times more accurately than without it. As previously mentioned, the amplification can be increased further by changing the galvanometer sensitivity control.

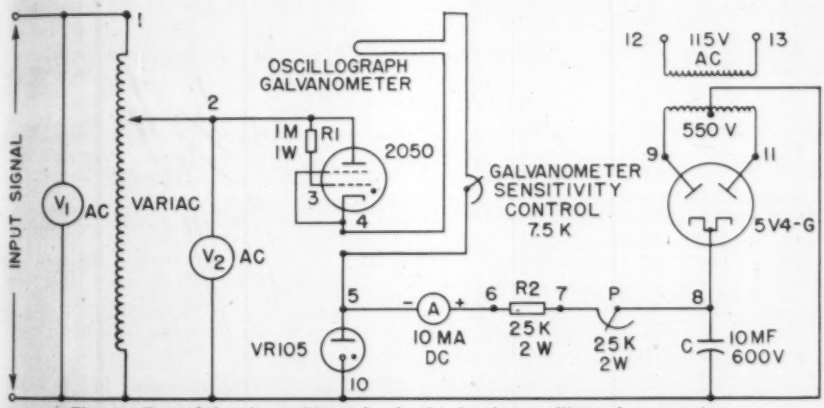


Fig. 1. Expanded-scale oscillograph circuit showing oscillograph connection.

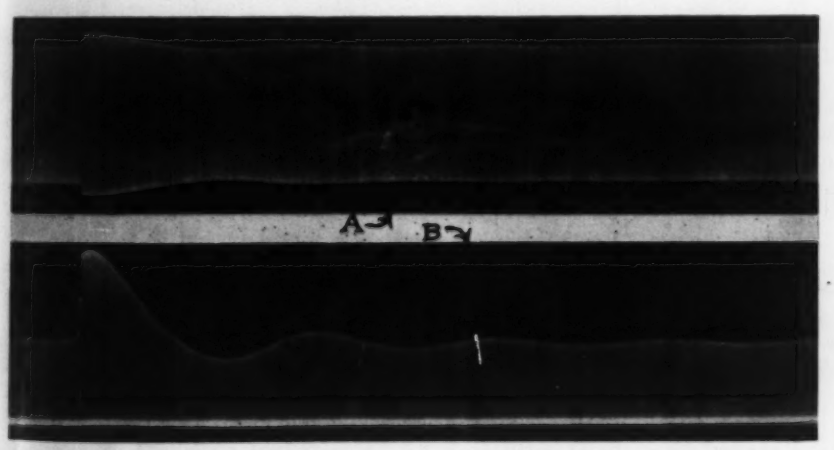


Fig. 2. Oscillogram pictures of voltage-wave envelope of 400-cycle a-c. generator output voltage turning off load. (A) Without expanded-scale oscillograph connected; (B) With expanded-scale oscillograph connected. [Ed. Note.—Illustration is five-eighths actual size.]

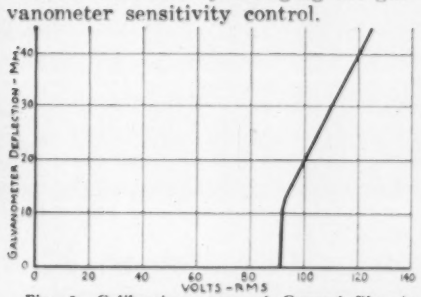


Fig. 3. Calibration curve of General Electric PM-12 two-element magnetic oscillograph.

"HEAT INERTIA" *in* Problems *of* AUTOMATIC CONTROL *of* TEMPERATURE

By VICTOR BROIDA, Consulting Engineer, Paris, France

PART III

ACTUAL CONTROLLERS

Continued

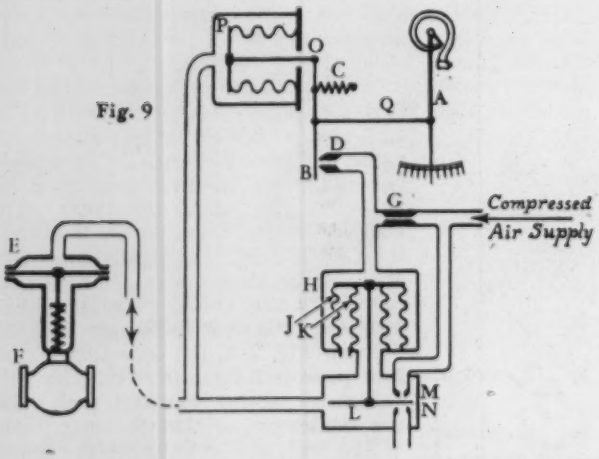
POSITIONING-TYPE CONTROLLERS

As we have seen, Floating Control can be considered as a continuous method of control only under some conditions, outside of which it is transformed into discontinuous control, this transformation being reversible as, under some conditions, "High-low" or "On-off" control can be transformed into Floating Continuous Control.

We shall study now the two types of automatic temperature controllers the operation of which is unconditionally continuous: the Positioning Continuous Controller and the Positioning Continuous Controller with Automatic Reset.

Fig. 9 is a schematic drawing of an air-operated positioning automatic temperature controller. We shall find in this drawing the same elements as in Fig. 8 and, in addition, a compensating

Fig. 9



bellows P connected to the same air tubing which feeds diaphragm E of controlled valve F and subjected therefore as well as this diaphragm to the same air pressure governed by amplifying pilot valve H.

This compensating bellows determines the position of pivot O of flapper B. This position is not fixed, as in the discontinuous controller, Fig. 8, but depends on that of compensating bellows P.

In this way, when the balance existing at a given moment between the heat input to the heating unit and the heat output carried away by the heated medium exists no more and when the temperature in this heating unit departs slightly from the original temperature of balance, the movement of pen A to the right or left of its initial position of balance rotates flapper B around its pivot O and thus decreases or increases the flow of air through nozzle D as compared to what this flow was during the preceding period of balance.

This results in an increase or in a decrease of the pressure exerted on bellows J of amplifying pilot valve H and this change of air pressure is consequently amplified and transmitted to diaphragm E of controlled valve F and simultaneously to compensating bellows P.

In this way, while the controlled valve closes or opens to a given extent corresponding to this variation of air pressure, compensating bellows P moves to the right or to the left and carries in the same direction pivot O of flapper B. This flapper thus receives a new motion to the left or to the right, i.e., in a direction *opposite* to that of its original motion resulting from the direct action of pen A. Its position, which was inclined with respect to that of nozzle D, becomes again perpendicular to this nozzle. Thus, the reaction of compensating bellows P tends to bound the decrease or the increase of the air flow through nozzle D resulting from an original action of pen A (corresponding to a slight deviation of the temperature in the heating unit).

If the temperature in the heating unit continues to increase or decrease, pen A and flapper B continue to move to the right or left of their initial position of balance but, in this movement, flapper B always remains perpendicular to nozzle D instead of becoming more and more inclined with respect to this nozzle (as would be the case with a "High-low" or an "On-off" controller) and thus moves in a way parallel to itself.

Indeed, this flapper always remains vertical because to each immediate action of pen A, rotating flapper B around its pivot O, will correspond an equally immediate reaction of compensating bellows P moving pivot O and straightening the flapper.

In this way, to each position of flapper B under the opposite actions of pen A and of compensating bellows P will correspond: (1) a definite temperature governing the position of pen A and, therefore, that of the link point of lever Q with flapper B and (2) a definite air pressure—obtained by an appropriate position of baffle L between ports M and N and by a given flow of this air through exhaust port N—this pressure governing the position of pivot O which is on the same vertical line as the link point positioned by A.

Furthermore, this air pressure determines a definite position of controlled valve F so that—in a way opposite to that of a discontinuous controller, in which the movement of flapper B is not limited by any compensating device—this flapper has its movement bound, as each of its successive positions corresponds simultaneously to a given temperature and to a given position of the controlled valve. This absolute link between the temperatures in the heating unit and the corresponding positions of the controlled valve is the peculiar feature of a positioning continuous controller.

The movement of flapper B in one direction or in the other continues in the described way until the moment when the temperature change inside the heating unit and the resulting movement of pen A stop owing to a change in the position of the controlled valve insuring again a balance between the altered heat output and the new value of the heat input.

It is obvious that this new balance takes place for a new position of flapper B and of pen A, hence for a corresponding new temperature inside the heating unit—both different from those corresponding to the previous balance. The positioning continuous controller therefore is not isothermic. This practical conclusion is identical with our previous theoretical conclusions.

The adjustment of the amplifying action of the controller under review is accomplished by altering the action of bellows P on the position of pivot O. This means, for a given temperature variation inside the heating unit, a more or less amplified movement of pivot O under the action of compensating bellows P. This means also that for a given temperature change in the heating unit, the relative opening or closing of the controlled valve can be increased or decreased.

Now let us recall the important relation obtained in Part I for

Continued on Page 450

What happens when you hear? What happens *inside* your ear when sound waves come in from a telephone conversation?

Bell Telephone Laboratories scientists have developed special apparatus to help answer these questions, for the telephone system is designed to meet the ear's requirements for good listening.

In the test pictured above, the young lady sits before loudspeakers in a soundproofed room with a small hollow tube, reaching just inside the ear canal. Sounds differing slightly in frequency and intensity come from a loudspeaker. The subject seeks to tell one from another, recording her judgment electrically by pressing a switch.

Meanwhile, the same sound waves pass down the hollow tube to a condenser microphone, and a record is made of the exact sound intensities she identified. Results help reveal the sound levels you can hear clearly and without strain—the sounds your telephone must be designed to carry.

Scientists at Bell Telephone Laboratories make hundreds of tests in this manner. It's just one part of the work which goes on year after year at the Laboratories to help keep Bell System telephone service the finest on earth.

BELL TELEPHONE LABORATORIES

Exploring and inventing, devising and perfecting, for continued improvements and economies in telephone service.

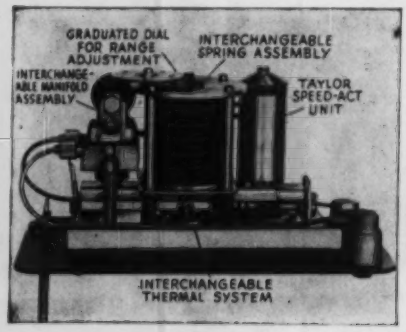
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 463

Temperature Transmitter

New "Transaire With Speed-Act" force-balance type pneumatic temperature transmitter is designed for applications where it is desirable to have indication, record or control remotely located from point of measurement and



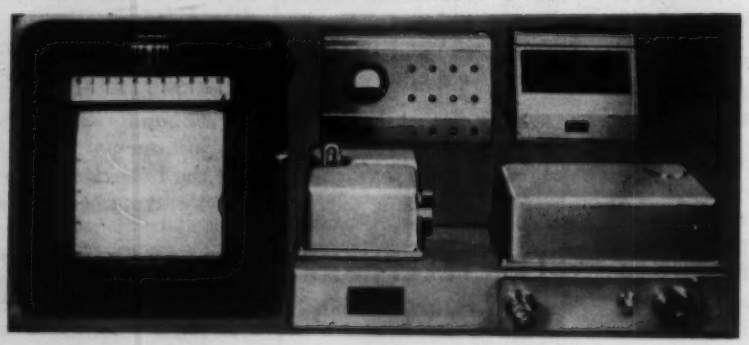
where it is necessary to have accuracy, high speed of response, small thermal elements and short range spans within limits of −375 and 1000 deg. F. Feature is incorporation of "Speed-Act" which applies principles of "Pre-Act" (derivative action) directly to temperature determination, which is said to be a new measurement technique developed by maker. "Speed-Act" is said to overcome lag inherently present in response of "any form of thermal measuring element" and to make possible "a quality of measurement not before attainable with any temperature measuring element, particularly those requiring separable wells." Transmitter's output in psi is proportional to temperature of its thermal element and, by means of 0.25-in O.D. copper tubing, this pressure change can be transmitted to a recording or controlling receiver located as far as 1000 feet away (or farther depending on conditions). Other unique features: (1) cigarette-size thermal elements contribute to high speed of response as well as convenience of installation; (2) Short range spans permit closer readings; (3) adjustable operating ranges; (4) Fixed air output range of 3 to 15 psi for full temperature span is linear to 0.1 percent assuring repeatability of readings; (5) Compensation for barometric and ambient temperature changes; (6) Interchangeable unit assemblies; (7) Thermal systems withstand overrange temperature up to 1000 F. Illustration shows components; case not shown gives adequate protection from dust and moisture.—*Taylor Instrument Companies, Rochester 1, N. Y.*

Mention No. 501 when filling out card

Automatic Continuous Analyzer

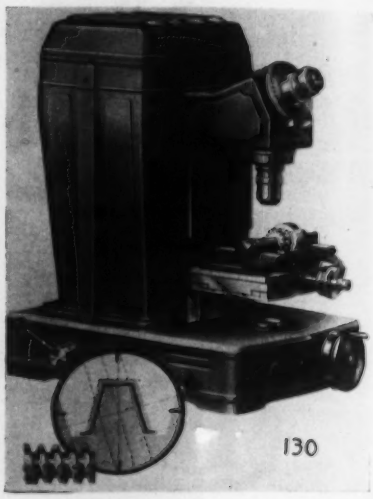
New "Model 12-D Infrared Analyzer," for continuous automatic analysis of as many as six different components in flowing liquid or gas phase stream, consists of: 1) infrared monochromator, similar to that used in maker's infrared spectrometer; 2) turret, automatically driven, twelve point (one reference standardization point and one absorption point for each of six components; 3) recorder, L & N 12-point, strip-chart, specially designed for this instrument, automatically synchronized with turret, and 4) amplifying circuit, highly stable, a-c. operation; compensates for changes in ambient temperature, source intensity, window dirt, etc. Cycling time for six-component analysis is about 6 min. Analyzer is particularly time-saving in pilot plant in determining optimum process conditions. Operating variables such as temperature, contact time, flow-rate, etc., may be varied continuously and evaluated immediately from automatic analytical record. In continuous, multi-stage process, sampling may be performed at intermediate stages for independent evaluation. In process plant, instrument provides permanent, accurate record of product concentration and purity as well as immediate indication warning of process troubles. —*Perkin-Elmer Corp., Glenbrook, Conn.*

Mention No. 502 when filling out card



Profile-measuring Microscope

New profile-measuring microscope, of Swiss manufacture and available here for first time, is said to eliminate all

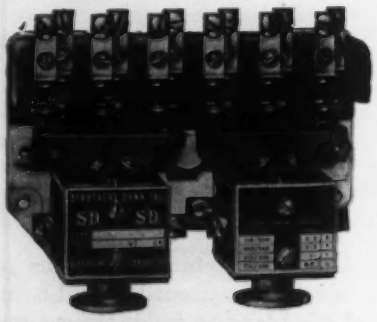


necessity of graticules and is far superior for checking bore diameters, pitch and angle of screw threads, for checking cutting angles of tools, gages and templates, for making coordinate measurements and for checking profiles. Instrument compares enlarged projected image of object with similarly enlarged drawing. Magnification may be varied between 6 and 50 times. Image of drawing appears in red in eyepiece and image of object is green. Maximum diameter of object observable is about 3.5 in.—*Hauser Machine Tool Corp., Manhasset, N. Y.*

Mention No. 503 when filling out card

Reversing Contactor

New "Type 175KXX" small reversing contactor is constructed for continuous duty control of a-c. or d-c. equip-



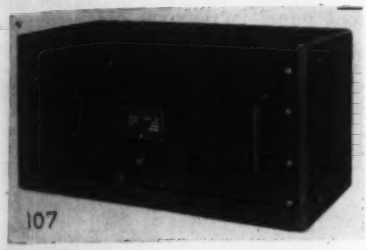
ment such as motorized valves. Ratings are from 1 to 2 hp. and 115 to 550 volts. Contactor consists of two 3-pole solenoids for forward and reverse opera-

tion mounted on common frame and mechanically interlocked to prevent simultaneous closure. Contacts are completely insulated. Auxiliary contacts can be added for electric lock-up or interlock. All fixed contacts are interchangeable as are moving contacts and corresponding parts on each solenoid.—*Struthers-Dunn, Inc., 150 N. 13th St., Phila. 7, Pa.*

Mention No. 504 when filling out card

Instantaneous Voltage Regulator

New "Stabiline Type IE51005," 500 va. instantaneous voltage regulator has input voltage range of 95-135 volts; output voltage range adjustable between

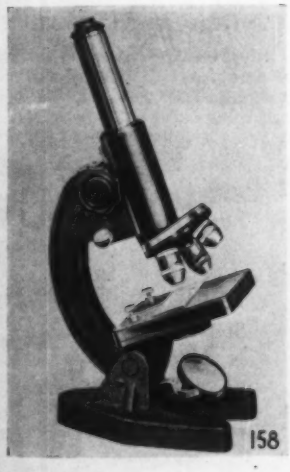


110 and 120 volts, and rated output is 0-500 va. Frequency in cycles is 60, plus or minus 10 percent. Load power factor range is given as 0.5 lagging to 0.9 leading and wave-form distortion is claimed never to exceed 3 percent. Stabilization is stated as plus or minus 0.1 percent of preset value; regulation as plus or minus 0.15 percent of present value. Recovery time is stated as 3 to 6 cycles.—*Superior Electric Co., 30 Hannon Ave., Bristol, Conn.*

Mention No. 505 when filling out card

Laboratory Microscope

New "Model F" laboratory microscope is said to feature "professional quality of lenses and mechanism at a cost of less than $100.00." It has a parfocal triple nosepiece and carries standard eyepieces and objectives of

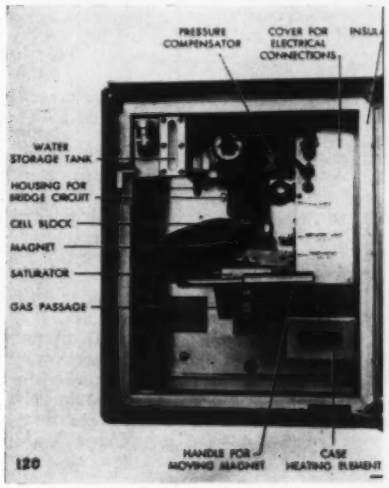


high resolving power. Its 4mm. dry objective will resolve structive of diatom Pleurosigma (classical test for performance). It has an adjustable draw tube as well as coarse and sensitive fine adjustment by means of cam shaft in separate dovetails. Every moving part can be compensated for wear. Substage is elaborate, is said to be "perhaps the most interesting feature." It consists of a removable condensing lens and an iris diaphragm which allows critical adjustment of light reflected from large plano and concave three-motion mirrors underneath, as is needed for oil immersion work. Instrument as available for immediate delivery is furnished with one eyepiece and three objectives, covering a range from 100 to 600 X. However, a complete line of standard eyepieces and objectives, including oil immersion, is offered permitting magnification up to 1500 X at high numerical apertures.—*Testa Mfg. Co., 418 So. Pecan St., Los Angeles 33, Calif.*

Mention No. 506 when filling out card

Oxygen Meter

New "Magno-Therm Oxygen Meter" is production model of oxygen recorder fully described in our Feb. 1948 issue,



page 170. Photo shows new analyzer unit. Recording instrument (which can be remotely located) is "Acratron Recorder," calibrated to read in percent oxygen. Measurement is compensated for ambient temperature, barometric pressure and variable moisture content of gas sample.—*The Hays Corporation, Michigan City, Indiana.*

Mention No. 507 when filling out card

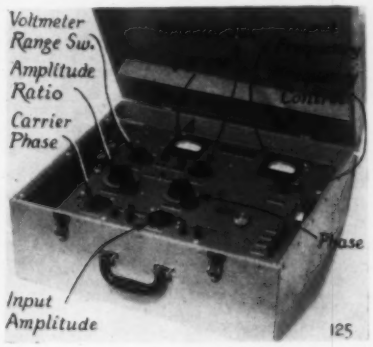
Coated Color Filters

New line of coated filters in all popular sizes and color densities (developed by EdnaLite Optical Co.) are high-vacuum hard-coated on both sides, matching effectiveness of a coated lens. They are permanently set in "Dura-Klad" free-floating rim which protects filter disk and makes filter shock-proof and easy to handle. "EdnaLite Filters" are available in all color densities for use with black-and-white film and four color densities for Kodachrome.—*Rodar Distributors, Inc., 95 Madison Avenue, New York 16, N. Y.*

Mention No. 509 when filling out card

Performance Analyzer for Automatic-control Systems

New "Type 6" model of "Servo Analyzer" (trade mark), for use with servo or automatic-control systems employing 60-cycle or 400-cycle a-c. error-measuring devices, is portable, requires no auxiliary test equipment. It eliminates

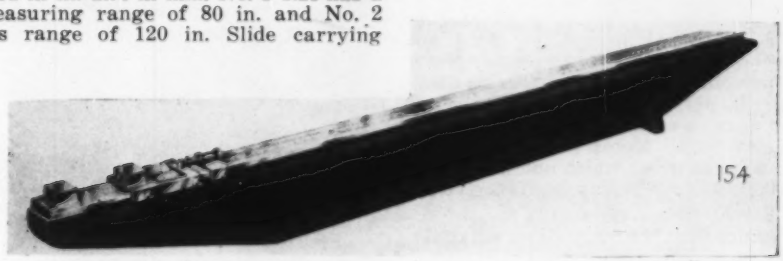


mathematical computations and guesswork in test procedures. It makes possible rapid over-all performance checks on servos and control systems for routine maintenance, for performance determination, or to determine optimum operating conditions. In speeding development work on new servos, etc., it should pay for itself in saving time of specialists. It fills need in educational institutions (and industrial-firm training departments) by making such concepts as "frequency response," "transfer func-

Measuring Machine

New measuring machine for external and internal measurements which is adaptable for use as a master check and for determining extremely accurate dimensions on pin gages, standard bars, and end measuring rods, makes measurements between hardened steel anvils (flat jaws may be substituted for round plugs). Precision steel scale is graduated in in. and in mm. No. 1 size has a measuring range of 80 in. and No. 2 has range of 120 in. Slide carrying vernier and measuring anvils is accurately fitted and a fine adjustment screw has been provided. Vernier easy reading, 2.450 in. long. Readings may be made very quickly and accurately without use of magnifiers. — *George Scherr Co., 200 Lafayette St., New York 12, N. Y.*

Mention No. 508 when filling out card



tion," etc., come to life as measurables. Incorporation of an a-c. VTVM (200 millivolts to 200 volts) is said to make new unit "ideal for test engineer or technician who must cover a large area" such as a plant, proving ground, ship, etc. Also, special tests may be run on phase-sensitive detectors, a-c. amplifiers with compensating networks, and other electronic equipment: two suppressed carrier-modulated a-c. voltages are available; relative envelope phase variable through 360 degrees. New unit can also be supplied for 800-cycle operation at no extra charge.—*Flight Research Engineering Corp., P. O. Box* 1-*F, Richmond* 1, *Va.*

Mention No. 510 when filling out card

Battery Tester

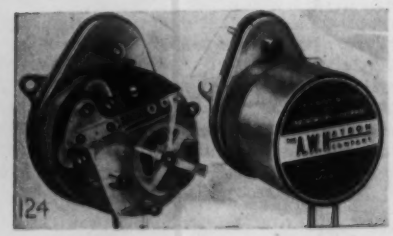
New "Model 698" pocket-size battery tester rapidly tests, under actual load, all dry batteries (1.5 to 90 volts) used in hearing aids, portable radios, etc.

Battery condition is shown instantly on "low-?-good" three-color scale; voltage readings may be made on calibrated scales. Unit has been designed also to indicate ability of battery to supply power required of it in actual use. Black molded case measures 3.06 x 5.88 x 2.56 inches, weighs 1.25 lbs.—*The Triplett Electrical Instrument Co., Bluffton, Ohio.*

Mention No. 511 when filling out card

D-c. Timing Motor

New "Series 5500 and 5700" primary time-power source for direct current applications has a marine-type escape-

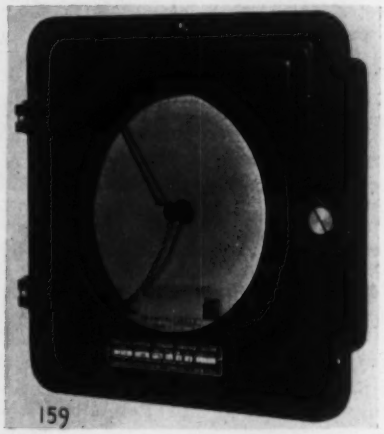


ment governor which is unaffected by wide variations in voltage, load and temperature. Accuracy of plus or minus 0.1 percent is claimed for "Series 5500" under 20 percent changes in voltage and plus or minus 1 percent for non-jeweled "Series 5700." Motor is geared to cam and balance wheel which operate control contacts.—*A. W. Haydon Co., Waterbury, Conn.*

Mention No. 512 when filling out card

Ampere-demand Recorder

New "Type CCAF Graphic Ampere Demand Meter," latest addition to maker's "Lincoln" watt-demand and

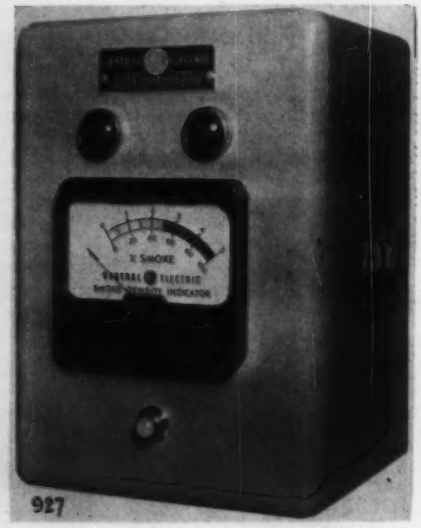


ampere-demand meters, provides a record of time and duration, as well as extent, of demand. Measuring element operates independently of watthour meter, is basically similar to that of indicating registering "Lincoln" demand meters. Demand record is not dependent upon time or "clock" mechanism, whose sole function is chart drive. There are no contacts. Demand at any time may be read from chart with no calculation other than application of chart constant and instrument-transformer constant. Slow movement of thermal demand meter minimizes maintenance and permits use of chart speeds as slow as 32-day rotation period. Chart drive option: synchronous-motor, or hand-wound Swiss-made high-torque fully-enclosed clockwork. New recorders available in 3-phase, 3-wire for averaging currents in three feeders according to their heating values; in two-range (6 and 7.2 amps.)—*Sangamo Electric Co., Springfield, Ill.*

Mention No. 513 when filling out card

Smoke Density Indicator and Control

New smoke density indicator and control consists of light source, phototube holder, and enclosure containing required control and incorporating an indicator calibrated in Ringlemann units,

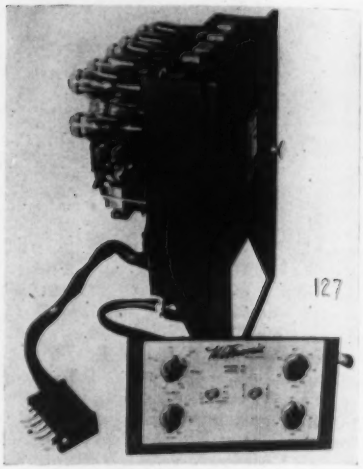


all in one unit. Recorder, either of continuous strip chart or circular "step" type, can be furnished. In operation, magnetic relay is set to operate when smoke density reaches predetermined level, at which time a blower forces over-the-fire heated air to firebox until smoke density drops to approximately 15 percent. Should smoke density again rise, relay is immediately energized. Each time relay operates, alarm is sounded.—*General Electric Co., Schenectady* 5, *N. Y.*

Mention No. 514 when filling out card

Sequence Weld Timer

New "NEMA 3B and 5B" relay firing timer employs standard thyratron tube. Front panel is removable for easy ac-

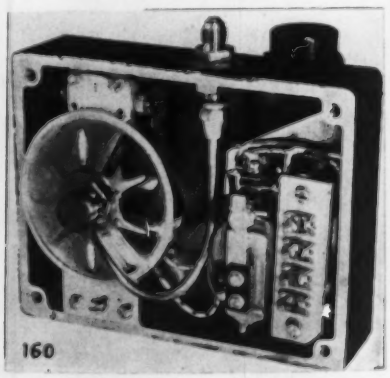


cess to components. Time period is independently adjustable. Timer features heavy-duty relays, and arrangement whereby panel holding timer dial and toggle switches can be wall-mounted or attached to side of welder. Illustration shows panel only with control panel unfastened.—*Weltronic Co.,* 19464 *West Eight Mile Road, Detroit* 19, *Mich.*

Mention No. 515 when filling out card

Nil-pressure Switch

New nil-pressure-actuated switch, for use as a safety device or to control electromechanical devices, is believed the first of its type to be offered. Its



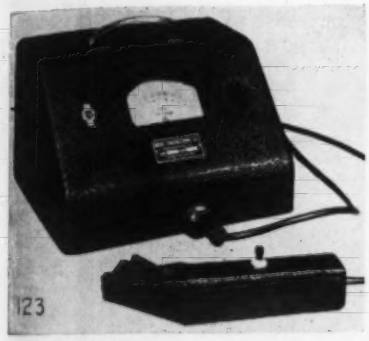
unique feature is a pressure-responsive element that operates an electric switch at a pressure as low as 0.1 inch of mercury above ambient and yet withstands a static pressure of 150 psi. Use of a relay and Micro Switch confines load

on Micro Switch to current required to actuate relay. Relay contacts are of adequate capacity to actuate most preventive and control mechanisms. New device, therefore, should find applications where severe pressure drops endanger lives or the proper functioning of machinery. Dimensions, 6.25 in. × 5.37 in × 3.31 in. Sealed cast aluminum housing excludes dirt and moisture.—*Meletron Corp., 950 North Highland Ave., Hollywood 38, Calif.*

Mention No. 516 when filling out card

Surface-roughness Comparator

New "Pico Surface Comparator" checks surfaces against an approved sample, and assures instant, accurate

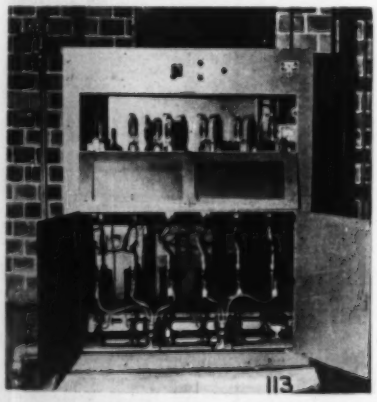


indicator readings. Simple, compact and portable, it can be used on production line, without special accessory equipment or specially skilled operators. Operates from any 110-volt, 60-cycle outlet. Comparator consists of indicator, exploring head and adapter. Readings are taken in 5 sec. by pressing head against surface being checked, touching actuating button and comparing indicator reading against master reading. Unit has knife-edge pointer, which reads only one point on scale, thus eliminating calculations or averaging. Area of exploration is said to be 500,000 times greater than with tracer methods.—*Merz Engineering Co., Indianapolis, Ind.*

Mention No. 517 when filling out card

Automatic Speed Controller

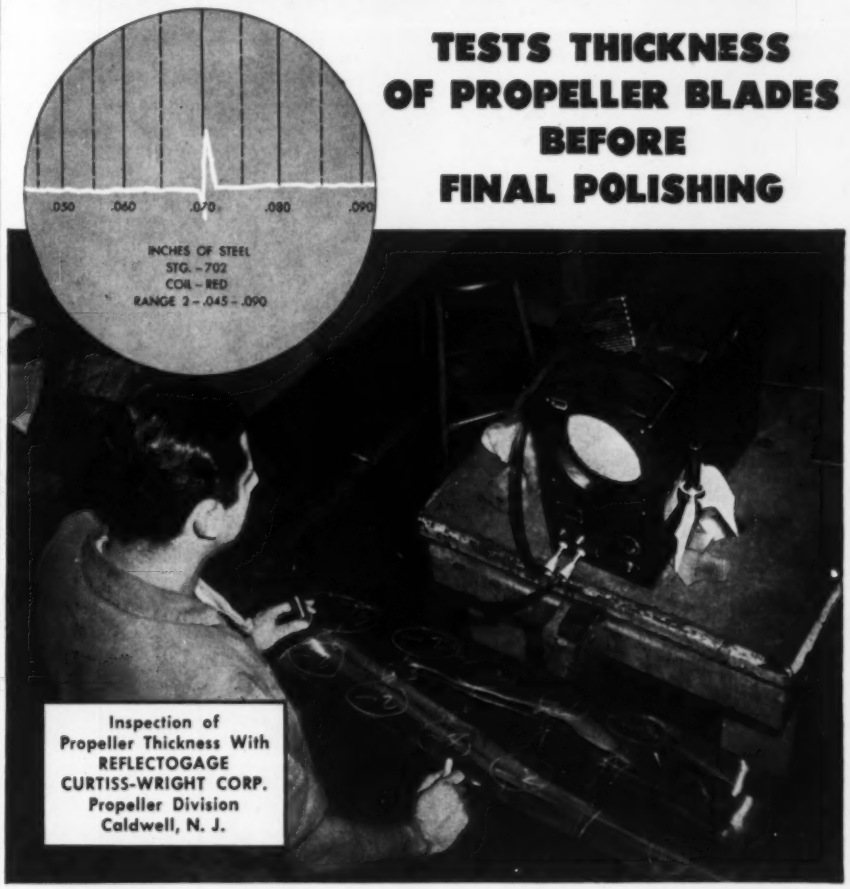
New "Varitronic" automatic speed control unit for machinery prime movers can be installed on existing equipment



or engineered as part of equipment at time of original installation. It is essentially a simplified system for utilizing flexible performance characteristics of d-c. motors, but operated from an a-c. power source. It embraces either con-

SPERRY REFLECTOGAGE

TESTS THICKNESS OF PROPELLER BLADES BEFORE FINAL POLISHING



Inspection of Propeller Thickness With REFLECTOGAGE CURTISS-WRIGHT CORP. Propeller Division Caldwell, N. J.

Leading propeller manufacturers use the Sperry Reflectogage to test the thickness of hollow propeller blades as a guide to final polishing. An inspector checks wall thickness at each blade station. This careful inspection provides a control of wall thickness throughout the blade within established wall thickness limits.

Propeller blades are only one of a large variety of fabricated parts which can be measured by the Sperry Reflectogage. Others include long tubes, formed hollow parts, blades and sheet stock, large tanks and boilers.

Operating on the principle of resonant frequency, the Reflectogage provides an economical means of measuring thickness of parts which formerly were inaccessible for convenient measurement.

In steel, the Reflectogage measures *directly* from .025 to .300 in. thickness, *indirectly* up to 4 in. Other metals and plastics can also be measured. Access from only one side is required. Accuracy is within plus or minus two per cent.

For full information on the Sperry Reflectoscope, write for your free copy of Bulletin 3700-K-5.

SPERRY REFLECTOSCOPE

Instantly, accurately locates smaller defects . . . penetrates deeper into metals than any other non-destructive testing device. Saves valuable time lost in machining defective material, minimizes rejects. Read all the facts on the Sperry Reflectoscope in Bulletin 3001-K-5. SP-143

SPERRY

SPERRY PRODUCTS, INC.
DANBURY, CONNECTICUT

stant torque or constant power, and control can be held within limits as close as 2 percent of basic speed. Use of "Varitronic" permits flexible remote push button control, dynamic braking, automatic reversing, inching, jogging, controlled acceleration and deceleration and control of input torque or power. Motor and brush life are lengthened because drive is engineered for a specific power range. "Varitronic" can be used with virtually any type of power-driven machinery.—*Industrial Associates, 8845 W. Olympic Blvd., Beverly Hills, Calif.*

Mention No. 518 when filling out card

Leather Thickness Measure

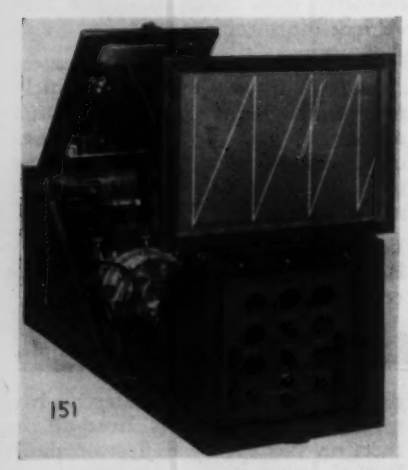
New "No. 25L Thickness Measure" can be carried in a vest or watch pocket for on-the-spot checks of hides, leather

strips and leather sheets. Easy-to-read dial is calibrated in oz., each garduation being equal to 0.25 oz. In addition, a small dial and pointer graduated in multiples of 8 oz. allow checking of leathers up to 20-oz. weight to the nearest 0.25 oz. Contacts are 0.25 in. diameter and open 0.3125 in. They are non-adjustable, thus assuring permanent alignment and parallelism. An unbreakable crystal protects dial face. A grain leather, snap-button case and complete instructions are furnished.—*B. C. Ames Co., Waltham 54, Mass.*

Mention No. 519 when filling out card

Portable Projection Oscilloscope

New "Model 701" portable projection oscilloscope produces a picture large enough to be viewed by large groups. Oscillogram is approximately 16 in.

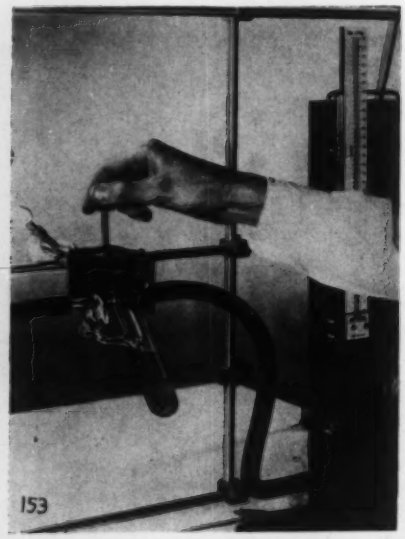


wide by 12 in. high. When folded up, cabinet is approx. 13 in. wide, 16 in. high and 19 in. deep. Uses of "Model 701" are in educational institutions where oscillograms of various waveforms can be viewed in a normally lit classroom. Other applications are in industrial monitoring, in experimental work, and wherever it is desired to have a transient phenomenon viewed by a large number of people at one time. New PPO has all the controls of a normal oscilloscope.—*Beta Electric Corp., 1762 Third Ave., New York 29, N. Y.*

Mention No. 520 when filling out card

Vacuum Pressure Regulator

New vacuum pressure regulator maintains vacua with high degree of sensitivity in range of 0.1 to 50 mm.



and is said to be advantageous in that it has no mechanical moving parts and is conveniently used in such procedures as distillations, extractions, sublimations, pyrolyses, etc. It also can be employed as a leak detector. Regulator has a range of 2 to 50 mm., with a sensitivity of plus or minus 0.05 mm. with mercury in reservoir, and a range of 0 to 4 mm., with sensitivity of plus or minus 0.01 mm. when butyl phthalate is employed. Fouling, loss of sensitivity and wear are eliminated by single-piece construction from Pyrex glass. In use, reservoir is tilted to a greater or less degree, thus changing head of fluid in reservoir and effecting control or pressure. A vertical micrometer control screw aids precise adjustment.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.*

Mention No. 521 when filling out card

Film-flutter and Wow Meter

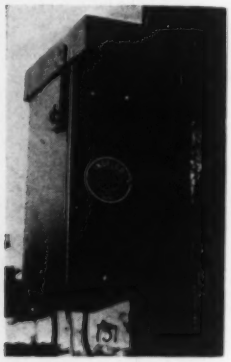
New "Model 491" analyzer for measuring flutter, wow and drift in sound heads, turntables and drive mechanisms,

can be employed with all types of disks, 16 and 35 mm. film, acetate film recorders, wire and tape recorders. It incorporates a high-gain amplifier and meets tentative standards of Soc. of Motion Picture Engineers. Three readings are shown simultaneously on 0.3, 1.0 and 3.0 percent scales. Limiter permits variation up to 30 db of input amplitude. —*Amplifier Corp. of America, 398-17 Broadway, New York 13, N. Y.*

Mention No. 522 when filling out card

Street Lighting Control

New photoelectric control for street lights is fully weather-proof and contains a cartridge-type unit which plugs

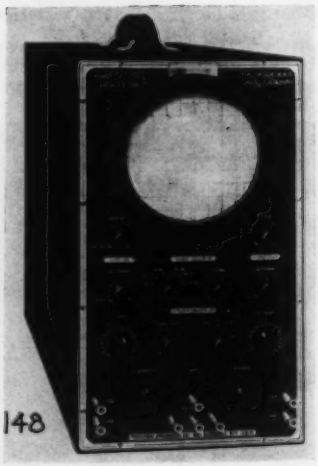


in similar to a fuse block. A 2-pole heavy-duty relay is rated at 25 amps. per pole. Switch can be used to bypass unit and turn on lights at will.—*Industrial Electronics, Inc., Hanover, Mass.*

Mention No. 523 when filling out card

5-in. Laboratory Oscillograph

New "Series ES-500" high-sensitivity cathode-ray oscillograph is a 5-in. laboratory type with extended range, voltage-regulated amplifiers for multi-purpose AM, FM and TV applications. It was specifically engineered for align-



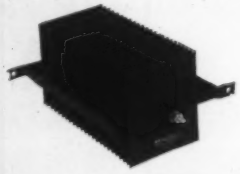
ment and adjustment requirements and is not to be confused with ordinary general-purpose oscilloscopes. Features include: Extended range vertical amplifier response to 1 mc. 2 megohm input resistance, approx. 20 mmfd. input capacity. 20 millivolt vertical amplifier

sensitivity permits direct alignment and adjustment of low gain circuits and examination of minute signal levels. Calibrated, frequency compensated, wide band "V" input step-attenuator. XI, X10, X100. Extended range horizontal amplifier response to 0.5 Mc. 500,000 ohms input resistance, approx. 20 mmfd. input capacity. Direct linear internal sweep coverage from 10 cycles to 30 Kc. Compensated multi-vibrator circuit.—*Precision Apparatus Co., Inc.*, 92-27 *Horace Harding Blvd., Elmhurst, L. I., N. Y.*

Mention No. 524 when filling out card

Selenium Rectifier

New "Model SE8M" high-voltage selenium rectifier rated at 5 milliamperes, is announced as "the smallest



completely sealed rectifier within its classification." Featuring a 0.375-in.-diam. tubular housing, it has two tinned pigtail leads and is designed for portable and sealed equipment involving low-current high-voltage requirements.—*Bradley Laboratories, Inc.*, 82 *Meadow St., New Haven, Conn.*

Mention No. 525 when filling out card

Beta-ray Thickness Gage

New beta-ray thickness gage, designed to measure continuously thickness of sheet materials moving along a conveyor without contacting or disturbing material, measures amount of beta-rays which are absorbed by sheet

material being checked. Device actually indicates mass per unit area of material under test, but equipment can be calibrated in terms of thickness to help operators maintain product uniformity, reduce amount of rejected material, and save on amount of raw material used. Source of beta-rays in gage is 2.5 millicuries of strontium 90, a radioactive isotope. Those rays unabsorbed by ma-

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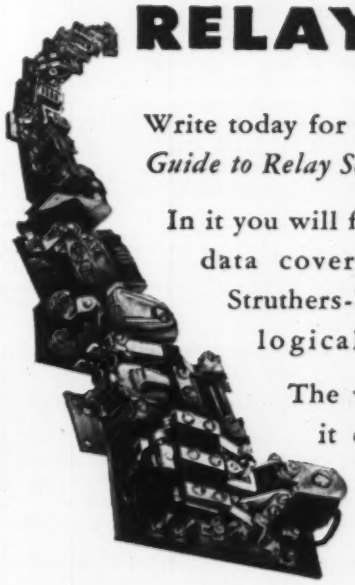

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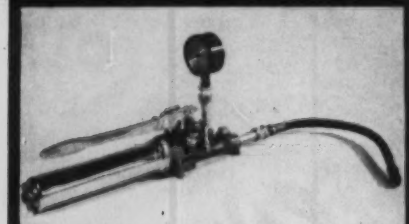
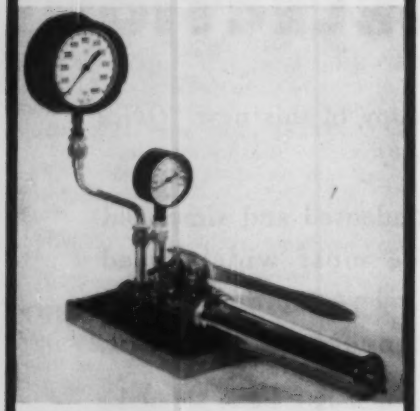
*Triple Purpose
PRESSURE TEST UNIT

Holds any pressure to 10,000 psi . . . for gages, instruments, valves.

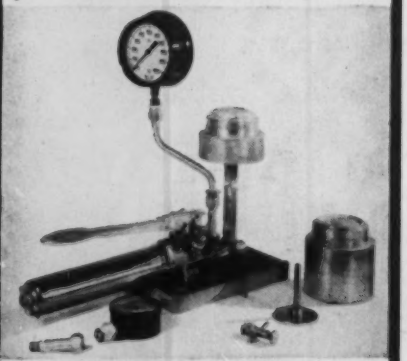
USE IT 3 WAYS



*1 PORTABLE PRESSURE TESTING for Weight, filled with oil, 8½ lbs.



*2 BENCH WORK WITH TEST GAGE for mounted on aluminum drip pan



*3 DEAD WEIGHT TESTING for shown with dead weight attachment mounted on unit.
Write for Bulletin

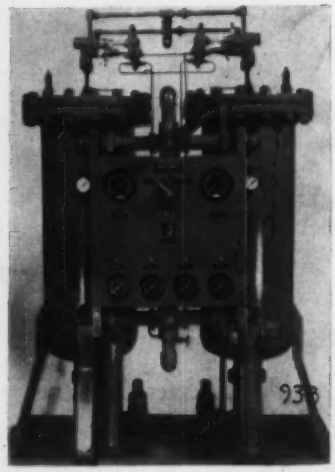
MANSFIELD & GREEN
1051 Power Avenue CLEVELAND 14 O

terial passing through gaging head are gathered in an ionization chamber. An attenuated 90-cycle signal is added in phase opposition to cancel signal from ionization chamber. Attenuator voltage, therefore, is a measure of ionization chamber voltage, and of amount of material in beta-ray beam. Accuracy is plus or minus 2 percent or better while drift is not more than 1 per cent per hour after a 30 minute warm-up period. Under normal conditions, calibration need not be made oftener than once every four hours.—*Special Products Div., General Electric Co., Schenectady 5, N. Y.*

Mention No. 526 when filling out card

Instrument-air Dehumidifier

New "Model 400 SISA" dehumidifier for instrument air supply service has twin towers, one being regenerated

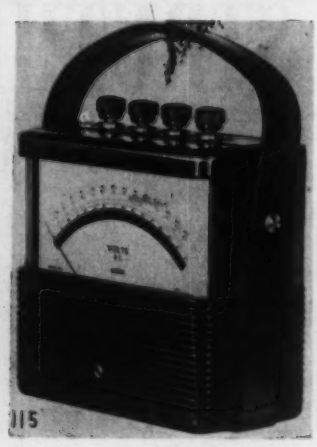


while other is absorbing moisture from instrument air supply line, or drying gases. Employs "Sovabead" desiccant; capacity is 50 to 1,000 scfm.—*Industrol Corp., 88-35 76th Ave., Brooklyn 27, N. Y.*

Mention No. 527 when filling out card

Portable Electric Indicating Instrument

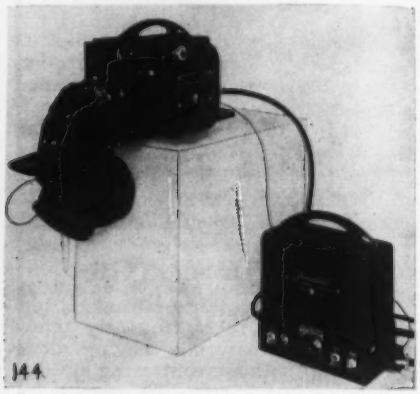
New "Model 901" series of a-c. and d-c. portable instruments have non-breakable windows that extend full width of instrument, curving around each side to reduce shadows, and providing brilliant illumination of large, readable 5.5-in. scales. Units are equipped with hand-calibrated mirror scales and knife-edge pointers. Instruments are shielded against external magnetic fields. D-c. units have a new self-shielding mechanism that provides such high protection that magnetic field created by a conductor carrying 7,000 amps at a distance of three feet from instrument causes an error in indication of less than 0.5 percent of full scale value. "Model 901" instruments are available as d-c. voltmeters, volt-ammeters, ammeters, milliammeters and microammeters; and "Model 904" of series is available as a-c. voltmeters, ammeters and milliammeters, all with accuracy within 0.5 percent. In addition, a series of a-c. rectifier type instruments is supplied as voltmeters and milliammeters with the same accuracy.—*Weston Electrical Instruments Corp., 617 Frelinghuysen Ave., Newark 5, N. J.*



Mention No. 528 when filling out card

Camera for CRO

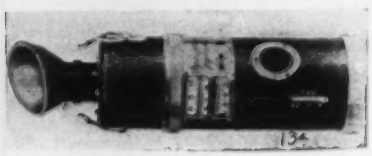
New model of "Oscillo-Record" camera incorporates "swing-away" film rollers for easier film loading and reduction of load on drive motor; self-oiling bearings throughout to eliminate need for frequent periodic lubrication; extra support on drive mechanism plate for greater rigidity; additional foot on camera cover casting for greater stability when camera is standing on bench or table; tell-tale indicator to show when film is moving (indicator will not operate when film is broken or jammed); separate transformer winding for data card lights; dynamic braking to bring film to virtually instantaneous stop when control unit is switched to "off" position.—*Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y.*



Mention No. 529 when filling out card

Open-hearth Optical Pyrometer

New model of maker's optical pyrometer has scale particularly suited for measurements of temperatures in open hearth furnaces; only critical range is shown, thereby increasing scale by 40 percent. Self-contained, direct-reading and weighing only 3.5 lbs., new instrument has blackbody scale graduated in

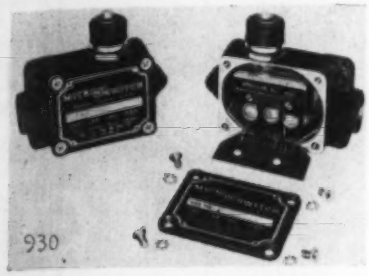


10-deg. divisions from 2200 to 3000 deg. F. for measuring temperatures of furnaces, oven linings and fire boxes. Red scale, similarly graduated, covers range 2400 to 3300 deg. F. and is corrected for emissivity of molten iron, steel, Monel and other ferrous alloys. —*Pyrometer Instrument Co., Inc., Bergenfield, N. J.*

Mention No. 530 when filling out card

Heavy-duty Microswitch

New "BAF1-2RN" precision switch for industrial use is recommended for severe service by reason of its high

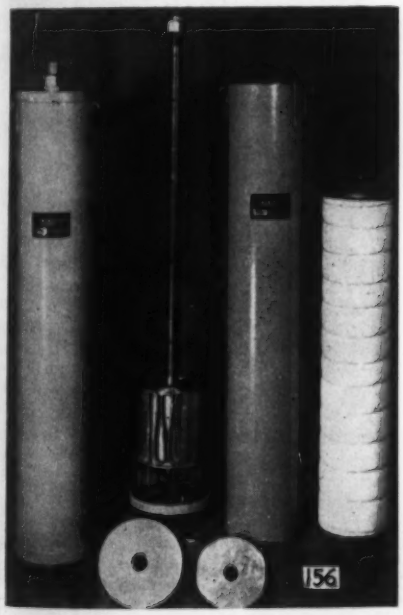


inrush capacity and high electrical rating. Underwriters Laboratory rating: 0.75 hp., 115 volts, a.c.; 1.5 hp, 230 volts, a.c.; 20 amps., 125 to 460 volts and 10 amps., 125 to 460 volts, a.c. "L". Switch has aluminum case suitable for recessed or surface mounting. D-t. switch has 2-lb. operating force, 1.75-lb. release force and maximum movement differential of 0.006 in. — *Micro Switch, Freeport, Ill.*

Mention No. 531 when filling out card

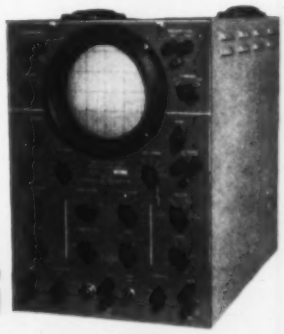
Instrument Air Dryer and Filter

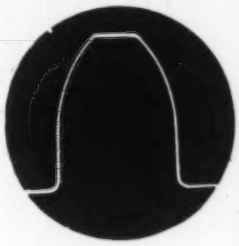
New "Condensifilter," especially designed for instrument air service, filters and dehydrates air and removes droplets. Illustration shows unit at left and components at center and right. Outer case is 8-in. steel pipe 52 in. long. Air



is admitted at bottom, through central tube, and is directed into condensing section. To get out of condensing section, air has to travel around scroll and pass over all coils of condenser, total

INSPECTION OF MOVING GEARS IS EASY with a DU MONT OSCILLOGRAPH



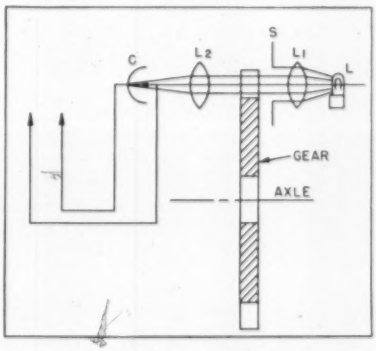


A perfect gear

An eccentric shaft

Irregular tooth size or angular spacing

★ Irregularity of toothshape and any eccentricity of a gear, in motion, is easily detected with the new methods of Du Mont Oscillography. Consider this simple test setup for examining a gear for regularity of tooth and concentricity of rotation:



Simple test setup

L is a source of light; L_1 is a lens; S is a narrow slit. Light is projected onto the gear as the gear rotates, the teeth varying the intensity of the beam in its passage to lens L_2, and photocell C. C is connected to the vertical amplifier of a cathode-ray oscillograph, such as the Du Mont Type 250 (illustrated). The sweep of the oscillograph occurs each time a tooth passes by.

If the gear teeth are uniform and if the gear runs concentrically, these facts will be shown on the oscillograph by a curve which looks like Fig. A—a uniform and stable curve.

If the shaft is eccentric, the curve will appear as in Fig. B; or if the gear teeth are not uniform, the curve will look like Fig. C.

Thus the characteristics of the gear in the machine may be examined easily and inexpensively under dynamic conditions through the new methods of Du-Mont Oscillography.

★ The foregoing is but one of many applications of Du Mont oscillographs to the varied problems of mechanical engineering. Du Mont carries a full line of cathode-ray instruments and tubes. Why not inquire now into the possibilities of applying a Du Mont oscillograph to your mechanical problem?

EQUIPMENT DEMONSTRATED—NO OBLIGATION

DUMONT *for Oscillography*

ALLEN B. DU MONT LABORATORIES, INC., PASSAIC, N. J.
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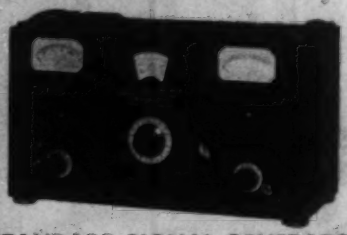
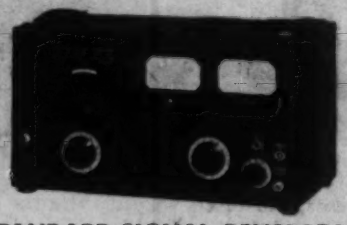
Laboratory Standards



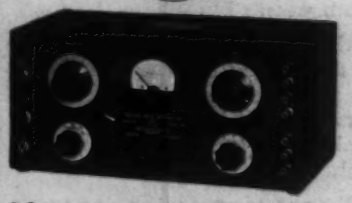
STANDARD SIGNAL GENERATOR

Frequency range: 75 kc. to 30 mc. Output 0.1 microvolt to 2.2 volts. MODEL 65B



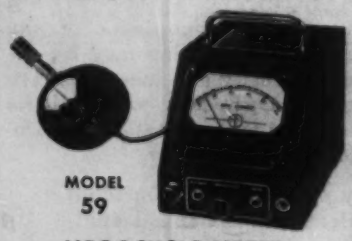
STANDARD SIGNAL GENERATOR

Frequency range: 2 mc. to 400 mc. Output 0.1 microvolt to 0.1 volt. MODEL 80



SQUARE WAVE GENERATOR

5 to 100,000 cycles. Recommended for AM, FM and television testing. MODEL 71



MODEL 59

MEGACYCLE METER

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

A versatile grid-dip oscillator covering the frequency range of 2.2 mc. to 400 mc.

CIRCULARS ON REQUEST

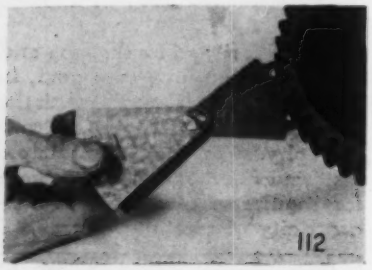
MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

length of which is 68 ft. Cold water, from any convenient source, is passed through condenser coils (inlet and outlet water connections are in bottom head). Water and oil condensed out of air drop down into water discharge section, where a snap-action trap blows down unit when condensibles have accumulated. From condensing section, air travels upward around outside of five cylindrical filter baskets nested together. Each basket is wrapped with six layers of canton flannel which acts as filtering medium. Air has to pass through all six layers before it can get into outlet section and out at top. Canton flannel can easily be removed and washed, or replaced with new flannel. "Condensifilter" can be opened and all parts made accessible or removed by unscrewing single holding nut on central hollow shaft.—*The Hankison Co.*, 1501 *Beaver Ave., Pittsburgh* 12, *Pa.*

Mention No. 532 when filling out card

Pocket-size Gear Gage

New gear gage can be carried in a tool box or in the pocket. It has 23 blades of diametrical pitches from 4 to

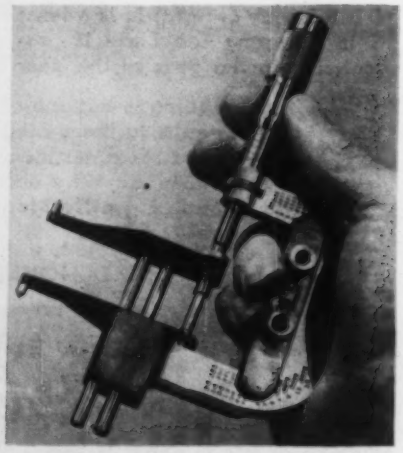


64 in 14.5 deg. pressure angles. Teeth are of correct involute shape. Segment blanks of each pitch are first turned in fixtures to conform to full diameter in accordance with number of teeth for full circle.—*George Scherr Co., Inc.*, 200 *Lafayette St., New York* 12, *N. Y.*

Mention No. 533 when filling out card

Internal-measurement Attachment for Micrometer

New "Microdapter" attachment for micrometers permits internal measurements otherwise inconvenient or inac-

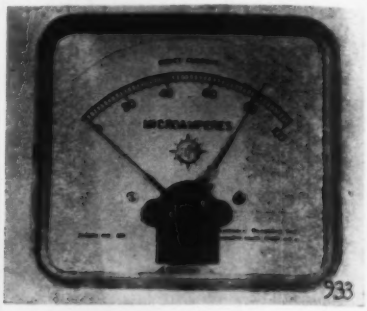


cessible: cone-shaped measuring points project beyond each leg; reach into grooves, recesses, behind shoulders, etc. Measurements are read directly on regular thimble with original micrometer accuracy. Available for 1 in. micrometers in 0.5 to 1 in. range; for 2 in. in 1 to 2 in. range; and for 3 in. to 2 to 3 in. range.—*Rimat Machine Tool Co.*, 1117 *Air Way, Glendale, Calif.*

Mention No. 534 when filling out card

Contact-making Instrument

New contact-making instrument (called "Meter Relay") is for use in automatic temperature control, automatic



gaging, sorting, etc. It provides positive contact on changes in current or voltage as little as 0.5 microamps. or fraction of millivolt. Contact is adjustable over scale arc. One platinum contact is on pivoted moving element; other is mounted on hand-set red pointer. Contacts, closed electromagnetically, can be opened manually or automatically as desired. Instrument has scale over 3 in. long.—*Assembly Products, Inc., Main at Bell St., Chagrin Falls, Ohio.*

Mention No. 535 when filling out card

Sound Pressure Meter

New "Model GA-1002A" sound pressure measurement equipment has been improved to include a specially isolated socket tip which effectively separates microphone clamping structure from preamplifier extension tube. This isola-

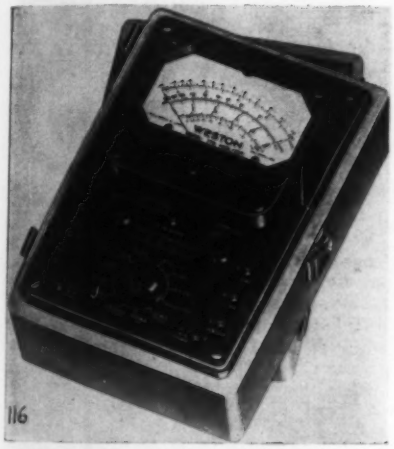
tion eliminates mechanical resonances that might otherwise result in extreme high-frequency range due to standing waves which could be set up in preamplifier extension tube under certain conditions of use. "H-101" standard microphone (part of equipment) has also been re-designed to provide more accurate polar symmetry of mechanical

structure resulting in exact acoustic symmetry about normal axis of microphone even at frequencies above 20 Kc. Dynamic range of new instrument is such that sound pressures from less than 1 dyne per sq. cm. to 20,000 dynes per sq. cm. (160-db. level) may be directly measured, and a times ten multiplier is available for extending upper range to 200,000 dynes per sq. cm. (180-db level). A built-in calibrating circuit permits setting system gain so that exactly 1 millivolt per dyne per sq. cm. is delivered across 10,000-ohm output circuit. Acoustic impedance of standard microphone is virtually infinite so that accurate sound pressure measurements may be made even in very high impedance environments such as inside small enclosures at higher frequencies. Complete lack of phase distortion permits exact reproduction of sound pressure transients over complete audible frequency spectrum.—*Massa Labs., 3868 Carnegie Ave., Cleveland, Ohio.*

Mention No. 536 when filling out card

Low-level Circuit Analyzer

New "Model 779, Type 5" analyzer for communication system maintenance—telephone, carrier current, and transmission line measurements—measures low-level speech circuits with a minimum of disturbance of these circuits.



It is entirely self-contained, requiring no power line connection. Being ungrounded, all problems of unbalance on transmission lines or signal circuits are eliminated. Analyzer makes dbm readings at all audio and carrier current frequencies. A-c. response is essentially flat to 50 kc. within 1 db over range minus 20 to plus 22 dbm, and is usable for comparative db readings on all common carrier current frequencies above 50 kc. Unusually low range (minus 20 to plus 2 dbm) is made possible through use of a newly-designed rectifier circuit with broad frequency and temperature compensation. It permits measurement of transmission line characteristics over long distances in presence of wide ambient temperature variations. The 1-volt a-c. range (minus 20 to plus 2 dbm) on "Model 779, Type 5," has an impedance of 2500 ohms, permitting its use as a bridging device with a minimum effect on relays and other line equipment components. In addition, a 600-ohm switching circuit converts analyzer to a terminating db meter on minus 20 to plus

For over fifty years Kester has been concerned with producing solder for every phase of industrial work. Take advantage of this experience by consulting Kester's Technical Department on all soldering problems. There is no obligation.

FREE—Technical Solder Manual Available on Request

Send for Kester's new solder manual, "SOLDER and Soldering Technique."

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Open Type "Can" Type With Plug-in Tube Base
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Delayed "Make" or "Break" Automatic Circuit Control
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Ruggedly constructed to exacting specifications that are carefully engineered to provide ample safety factor . . . quality all the way through!

Automatic's relays are not built to a price but to an unexcelled standard of performance. That's why they are the choice of so many "big name" manufacturers.

We engineer and build a wide variety of stock model relays for practically all applications. A staff of competent engineers will design and build relays to fit *your* requirements.

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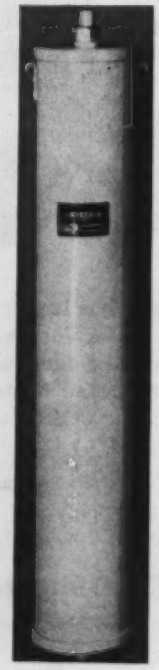

Removes water and oil vapors by cooling. Automatically discharges condensed vapors, filters air through seven layers of finest flannel.

Condensing section contains 68 ft. of 3/8" o.d. copper tubing, providing great heat exchange area.

Condensed vapors are automatically discharged through snap-action, float actuated, valve.

Filter cartridge, made of five concentric, expanded brass baskets, each wrapped with seven layers of canton flannel, furnishes over 15 sq. ft. of filter surface area.

Removal of one 1½" SAE nut dismantles entire filter for cleaning & service.

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2 dbm range. Complete ranges to 1000 volts a.c. and d.c., d-c. current from 100 microamps. to 10 amps., and resistance ranges from 1000 ohms to 10 megohms, along with a transmission measuring instrument calibrated in 0.5-db. steps, make this analyzer a general utility instrument.—*Weston Electrical Instrument Corp.*, 617 *Frelinghuysen Ave., Newark 5, N. J.*

Mention No. 537 when filling out card

H-f. Microvoltmeter Component

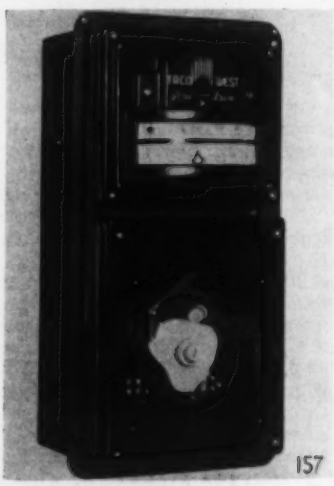
New "Megalyzer, Jr.," for measurement of voltages ranging from 100 to 10,000 microvolts and for high-frequency

spectrum analysis, has range of sensitivity that can be increased to include greater input voltages by attaching external pads. "Megalyzer, Jr.," is used in combination with "Mega-Sweep" and standard oscilloscope for h-f. spectrum analysis. When voltages are to be measured, combination of calibrated signal generator, "Mega-Sweep" and standard oscilloscope is required. New "Megalyzer, Jr." has frequency range from 30 to 500 Mc. (useful to 1000 Mc.) and a frequency sweep on display of at least 30 Mc. Frequency resolution is 100 Kc.—*Kay Electric Co., Pine Brook, N. J.*

Mention No. 538 when filling out card

Temperature-time Controller

New "Model CPR Time-temperature Program Controller" controls temperature by predetermined schedules. Upper section contains a modified "Model C Veri-Tron Electronic Controller," having plug-in compartmented construc-



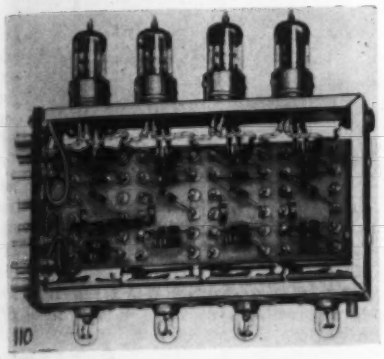
tion, high-rating snap-action control contacts, and featuring uniform control levels independent of line voltage variations. Lower compartment contains a synchronous-motor-driven cam which, by means of a simple back-lash-free linkage, positions control index arm of temperature controller as called for by

the cam contour. Cam may be sheared by the user to produce any desired time cycle on the printed disk. Safety clutches to safeguard mechanical drive are integrally provided. A full-gasketed glazed cover permits observing cam or cycle position at all times, also permits ready removal for changing cams, facilitates initial wiring as it assures unobstructed access to master barrier terminal block and conduit knock-outs. A large variety of standard and special scales, ranging from minus 300 F. to 3400 F. or C. equivalent, are available and may be coupled with two-position, multi-position, or proportioning control systems. Instrument is 9 in. wide, 8 in. high, 8 in. deep, designed for flush or surface mounting—*Dept. P, Taco West Corp., 515 N. Noble St., Chicago 22, Illinois.*

Mention No. 539 when filling out card

High-speed Counter Decades

New counter decades available separately for first time are similar to those used in maker's counters, scalers, etc.

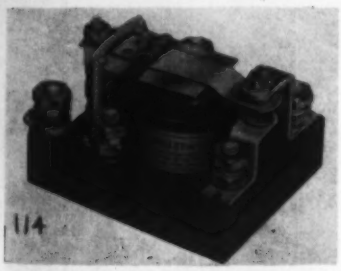


They are four-tube decade circuit type used in packaging, automatic machine control and similar industrial applications. Instrument has four direct-decimal readouts. No complex resistor matrix is employed. Counter is said to have extremely wide bias range which insures stable operation. Units can be connected in tandem for any registration capacity. Plug-in decade illustrated can be used at counting rate up to 130,000 per sec.—*Potter Instrument Co., Inc., 136 Roosevelt Ave., Flushing, N. Y.*

Mention No. 540 when filling out card

Aircraft Power-type Relays

New "Bulletin 103" magnetically-operated aircraft power type relays are suitable for remote and automatic con-



trol purposes where vibration and shock are encountered. Basic parts are mounted on a molded phenolic base with front-connected post type terminal inserts. Contact gap, tail spring and normally closed contacts are adjustable. D-c. re-

$5.07 saved a contract ...and a man's business

Special switches were needed to complete an electrical instrument contract. Late delivery of finished items would kill chances of future orders and lay off men. Switches were **1100** miles away, but Air Express delivered the **15**-lb. package at 3 A.M. — 8 hours after pick-up. Cost, only **$5.07.** Air Express now used regularly. Keeps down inventory, improves customer service by early delivery.

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12 lbs. of table delicacies goes 600 miles for $2.53.
(Same day delivery in both cases if you *ship early.*)

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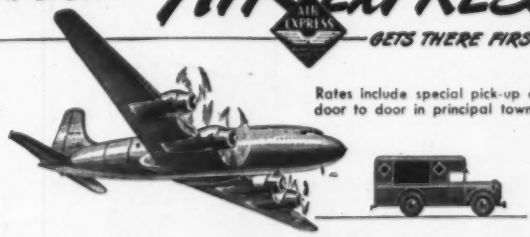

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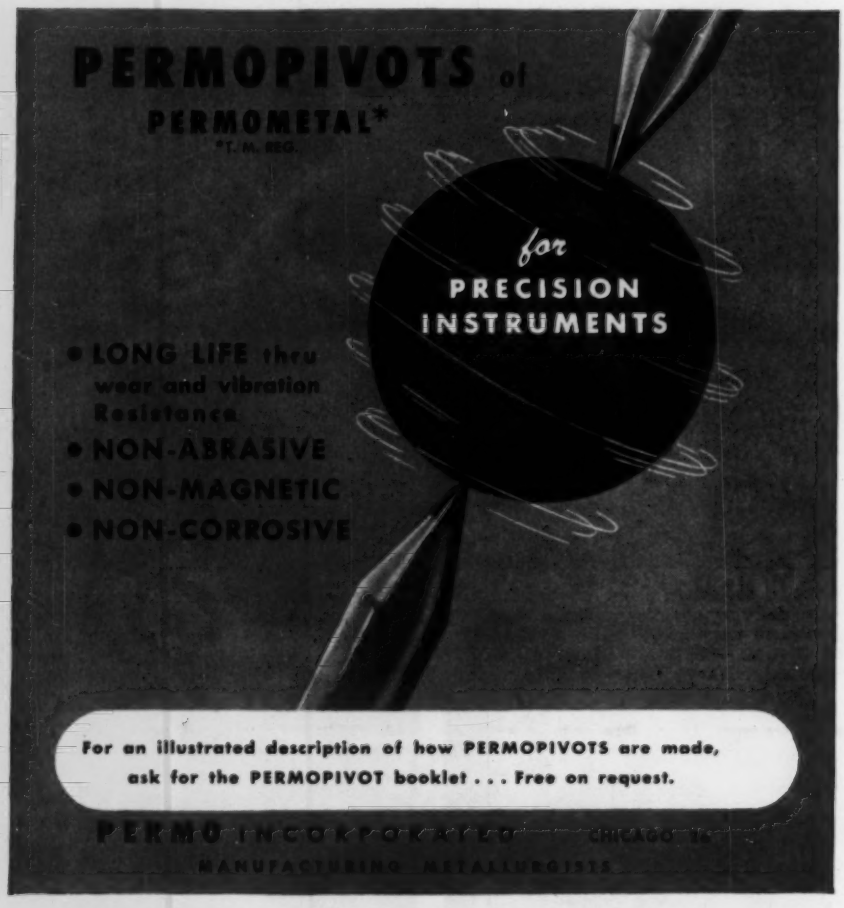

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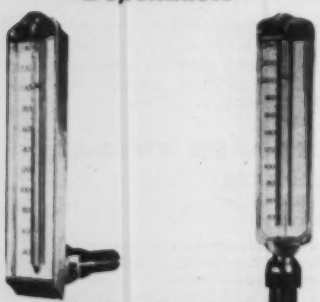

Case—Brush finished cast aluminum.
Well—Cast iron or brass. Sizes available are ¾" pipe thread by 3" or ½" pipe thread by 2" or 3" long.
Scale—Figures and lines are black on white background. Figures and lines are etched, background is silver plated. Length is 6" and range is 30° to 240°F. Ranges of 260° or 280° at top are available at slight additional cost.
Tube—Best grade magnifying lens front glass tubin. Actuating element mercury or red spirit columns.
Adjustment—Each thermometer is fitted with an adjusting screw to permit facing the front or scale of instrument to any position.
Can be furnished in straight or 90° angle type, as illustrated.
Each instrument packed in individual cardboard box. Customer's name in 1M lots on box.
Both instruments meet government specifications WWP 541, 1700E, 8000E.
Brine Line Range— —40 to 100°F. (Mercury tube)

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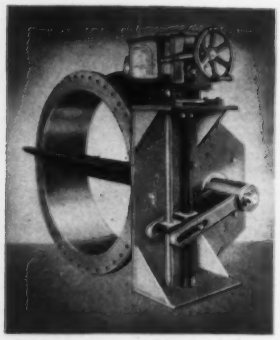
lays withstand acceleration tests above 10G and vibrations of 60 cycles and 0.03-in. amplitude. Standard s-p.d-t relays are rated as follows: N-O. contacts: 25 amps., 24V. d.c. or 115V a.c., 50-60 cy.; N-C. contacts: 2 amps. d.c. or 115V. a.c., 50-60 cy. Continuous-duty coils are available for operation up to 115V. d.c. or 230V. a.c., 60 cy.—*Ward Leonard Electric Co., Mount Vernon, New York.*

Mention No. 541 when filling out card

50-psi. Valve for Hydraulic Service

New 54-inch 50-psi. Iron Valve for hydraulic service has 125-pound American Standard flanges, is operated by a

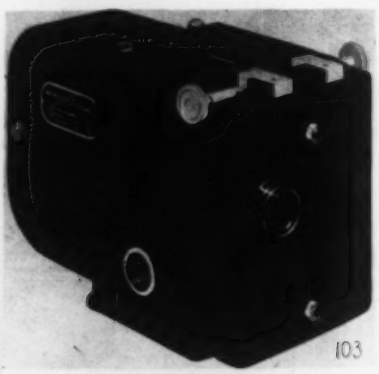


"Limitorque" electric motor connected to a threaded reach rod that moves valve slowly to prevent water hammer. Threads on reach rod can be cut for speeds from sixty seconds to eight minutes. Valve is available in larger sizes, for higher pressures and in materials other than iron.—*R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.*

Mention No. 542 when filling out card

Recording Camera

New "Model C Varitron" for photo recording of measuring instruments, fluoroscopes, oscilloscopes, etc., has all features of maker's "Portronic" except parallax-corrected full-sized viewfinder; is composed of three interchangeable



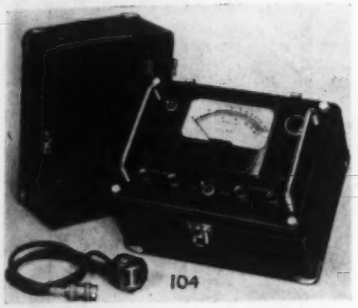
parts: (1) Shutter, electrically operated, completely automatic, with two sets of built-in contacts for controlling electronic flash lamps, counters, sequence timers, etc. (2) Body has no moving parts, allowing flexibility in camera design and choice of photographic lens. (3) Film magazine has motor and film metering equipment built-in; may be had for

35mm. or 70mm. sensitized stock, paper or film, perforated or unperforated. All magazines interchangable with any camera. In operation, camera is controlled by closing an electrical contact, either manually or by sequence time clock intervalometer, radio signal, sound, etc. When contacts are closed, shutter opens and closes and actuates two contacts in a pre-arranged sequence. A motor-starting switch starts film-wind motor that disconnects shutter. At end of film-winding cycle, shutter is automatically re-connected for next operation.—*Photographic Products, Inc., 955 N. Mansfield Avenue, Hollywood 38, Calif.*

Mention No. 543 when filling out card

Coating-thickness Gage

New "Coatingage" rapidly measures thickness of non-magnetic coatings on iron or steel without damage to coating;

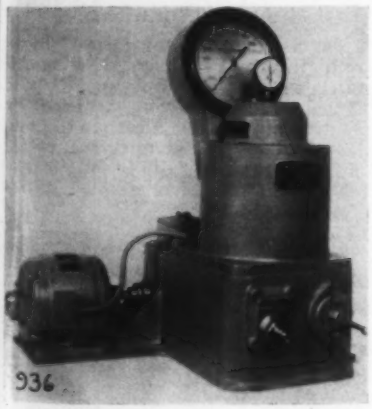


thickness is indicated directly on meter of instrument. Two concentric scales cover a range of 0.0001 to 0.50 in. Instrument's lightweight and self-contained battery power supply permit its use in field as well as in laboratory or on production line. "Coatingage" head contains a coil, connected to a bridge circuit, balanced for zero thickness. An increase in gap between coil and base metal unbalances bridge and causes current to flow through indicating microammeter. Thickness readings are within 10 percent of actual thickness.—*Branson Instruments, Inc., 436 Fairfield Ave., Stamford, Conn.*

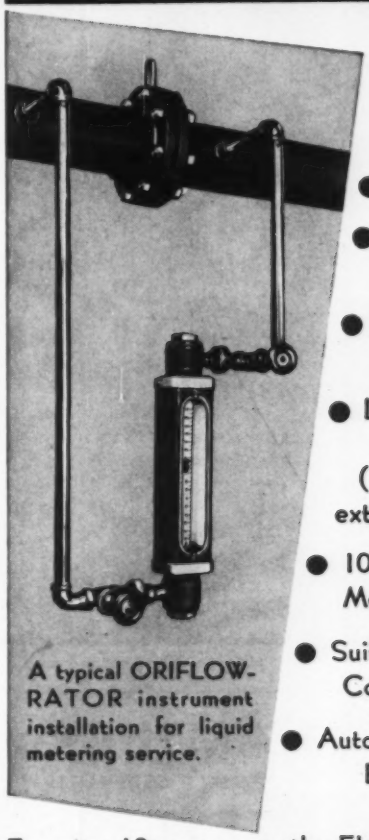
Mention No. 544 when filling out card

Ductility Tester

New bench model ductility testing machine for testing drawing qualities of sheet metal, has exceptionally fast cycle; speed of piston travel is adjustable within wide range by means of simple dial



In the new ORIFLOWRATOR meter Fischer & Porter offers you an ORIFICE METER with



A typical ORIFLOWRATOR instrument installation for liquid metering service.

- No Mercury! (or any other manometer fluid)
- No Seal Pots!
- No Equalizing Valves!
- No Overload Problem!
- Linear Calibration Scale! (no square root extraction required)
- 10 to 1 Accurate Metering Range
- Suitability for any Corrosive Fluid!
- Automatic Purging of By-pass Line!

For over 10 years now the FLOWRATOR meter (formerly rotometer) has been handling ever-increasing numbers of fluid metering problems for flows in pipe sizes from 1/8" to 4". Now, placed in bypass around a main line orifice the FLOWRATOR meter becomes the ORIFLOWRATOR meter and takes on the accurate wide range metering of any liquid, vapor or gas in any larger pipe size while giving you all the advantages listed above over ordinary "orifice meters". Any pressure, remote instruments actuated electrically or pneumatically, flange taps or vena contracta taps.

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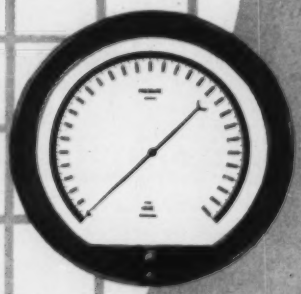
FISCHER & PORTER CO.

DEPT. 9Q-5C **HATBORO, PA.**

FLOWRATOR TRADEMARK

a bourdon tube of special design for every application



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Heise pressure gauges employ an infinite number of Bourdon tube designs to reduce fibre stress to a point where the gauge can be used continuously at maximum calibration. There is no standard design. Every Heise Bourdon tube is designed for maximum stability and accuracy in a selected range and pressure medium.

Three sizes: 8½ in., 12 in., and 16 in., in ranges from 0-15 to 0-10,000 psi. Prices from $151.60 to $211.20. Write for catalog.

Heise Bourdon Tube Company, Inc.
Newtown, Connecticut

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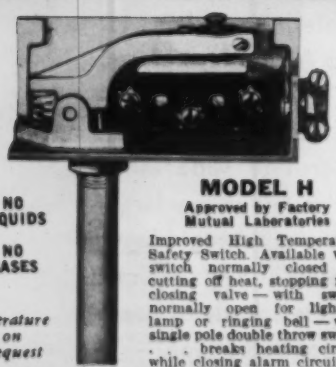
TEMPERATURE
LIMIT SWITCHES



NO LIQUIDS

NO GASES

Literature on Request

MODEL H
Approved by Factory Mutual Laboratories

Improved High Temperature Safety Switch. Available with switch normally closed for cutting off heat, stopping fan, closing valve — with switch normally open for lighting lamp or ringing bell — with single pole double throw switch . . . breaks heating circuit while closing alarm circuit.

• Accurate, Rugged, Dependable. • Corrosion and heat resisting tube. • Dial Pointed for easy setting inside case. • Locking screw locks temperature setting. • Terminal plate has large screw terminals. • Snap-action Micro-Switch eliminates contact troubles. • Range minus 100° to 1400°F. Adjustable range 200. • Dimensions—5⅛" x 1¾" x 3".

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12 Years Experience Manufacturing Temperature Controls

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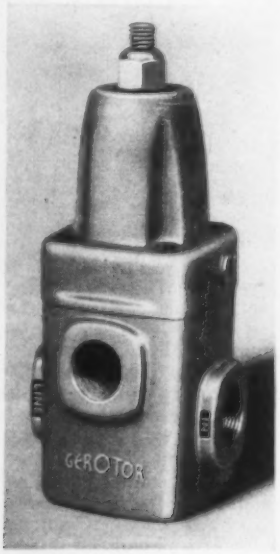
setting, and complete tests in as little as 15 seconds are possible. Tester is built with capacity of 15,000 lbs. to cup test material up to 0.125 in. in thickness or 30,000 lbs. for material up to 0.25 in. in thickness. Tester is motorized and hydraulically operated. It incorporates two concentric pistons; outer piston grips test piece against head at top of machine; inner piston makes cup in specimen. Pressure gage, fully protected against overloading, incorporates maximum indicating hand to show pressure at which yield in the specimen occurs. Depth indicator shows depth of draw at any moment by direct reading.—*Steel City Testing Machines, Inc.* 8843 *Livernois Ave., Detroit 4, Mich.*

Mention No. 545 when filling out card

Hydraulic Sequence Valve

New "Model 8822" sequence valve prevents flow into branch circuit until pressure in main circuit has reached a

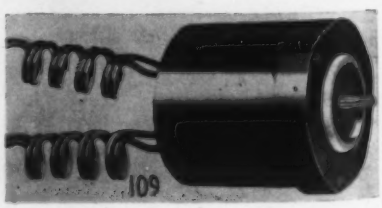


predetermined amount. Improved features include hydraulically-balanced piston with extra-large bearing surface; spring guide; single-diameter bore; and large-diameter plunger. Direct operated by "IN" port pressure, valves are available in two pressure ranges of 50 to 500 psi., and 500 to 1500 psi., with adjustment from minimum to maximum in each range. 7 sizes range from 0.25 in to 1.5 in.—*Gerotor May Corp., Baltimore, Md.*

Mention No. 546 when filling out card

A-c Servomotor

New a-c. servomotor is said to feature high torque, high speed, low inertia, small size and light weight. Motor is a 400-cycle, 115 volt, two phase, four pole induction motor with a torque to inertia ratio of 26,300 radians per sec. per sec. Motor will reverse fully in 0.2 sec. from 11,200 rpm. It delivers 2.5 oz-in. stall



torque which varies directly with control winding voltage. Motor is 1.75 in. in diameter by 1.75 in. in length and weighs 6.1 oz. Feature of servomotor is that it will stop rotating when excitation of control winding is reduced to zero. This motor is especially adaptable to high-performance servo systems used in radar, automatic pilots, computers, etc. For applications where higher acceleration is more important than small size and light weight, another new four-pole servomotor has a torque to inertia ratio of 46,000 radians per sec. per sec., with a stall torque of 3.8 oz.-in. It is 2.3 in. in diameter by 2.1875 in. in length and weighs 15 oz. — *Kollsman Instrument Div., Square D Co.*, 80-08 45th *Ave., Elmhurst, N. Y.*

Mention No. 547 when filling out card

Gage Blocks

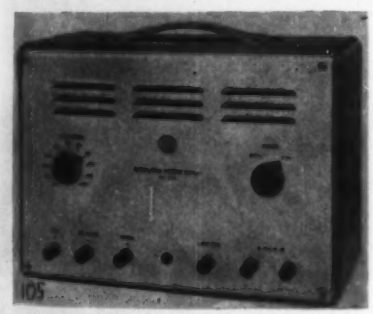
New set of 83 gage blocks is made by new process said to eliminate possibility of burrs and thereby extend use-

ful life of gages by 100 percent. New blocks differ from those previously available in that a final manufacturing step, after conventional lapping to produce mirror finish, introduces a second parabolic curve on all eight edges so that wire edges produced during lapping are removed. Maker states that wire edges often are "bent upward" by gage striking a hard surface and that a burr only 2 millionths of an inch high renders gage useless.—*Gage Div., DoALL Co., Des Plaines, Ill.*

Mention No. 548 when filling out card

D-c Power Supply

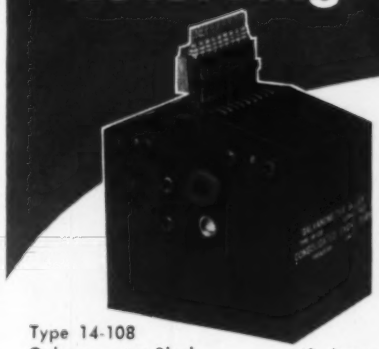
New "WP-23A Regulated Power Supply" is a source of highly filtered d-c. power; supplies a d-c. voltage continuously adjustable from 0 to 300 volts



which remains virtually constant regardless of line-voltage fluctuations and varying load currents encountered in development work. Primarily intended as a stable "B" supply, unit is also useful as a low-impedance "C" bias source. Both output terminals can operate above ground potential, as required.

F.M.* —THE REAL MEASURE OF PERFORMANCE IN

Recording Galvanometers!



Type 14-108 Galvanometer Block (9-element)

***FIGURE OF MERIT**

(Sensitivity X Resonant Frequency²)

IN THE FIELD of Recording Galvanometers the primary desire is to have maximum sensitivity over a maximum frequency range. To provide a comparative rating by which all makes of galvanometers may be judged, Consolidated Engineering has set up a Figure of Merit, with sensitivity and frequency range the prime criteria.

Galvanometer sensitivity varies inversely as the square of the resonant frequency, other factors remaining constant, and both are determined by the design and construction of the instrument. The Figure of Merit is then determined by multiplying the Sensitivity (in millimeters per microampere per meter) by the Resonant Frequency (in cycles per second) squared, $FM = SF_r^2$. This Figure of Merit is based on current sensitivity.

Consolidated Galvanometers, long the accepted standard in many industries and governmental agencies, rate a high Figure of Merit in all types and models. We are proud of this rating—a rating brought about through experience, know-how, and expert craftsmanship.

The wide range of frequencies and sensitivities offered in the two series of Consolidated Galvanometers furnishes 20 individual instruments to choose from to best fit your needs. The 7-100 Series are 4.5 inches long and 0.24 inches in diameter. The 7-200 Series are 2.75 inches long by 0.1625 inches by 0.1825 inches, the smallest commercial galvanometer available. Both of these series are produced in frequencies up to 2000 cps. Magnet Blocks are available for mounting galvanometers in various numbers up to 36.

The quality and accuracy of Consolidated Galvanometers have played an important role in Consolidated's leadership in the design and manufacture of Recording Oscillographs.

An informative 12-page bulletin on Recording Galvanometers has been prepared by Consolidated and is available, without charge, by writing for Bulletin CEC-1501-X1.

For information on Consolidated Recording Oscillographs, write for Bulletin CEC—1500—X5.

CONSOLIDATED GALVANOMETERS—*Leaders in the Field*

CONSOLIDATED ENGINEERING CORPORATION

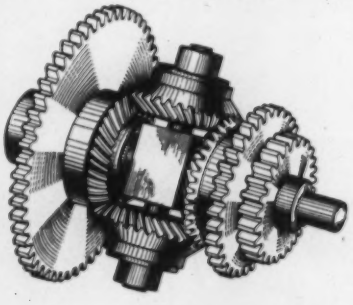
Analytical Instruments for Science and Industry

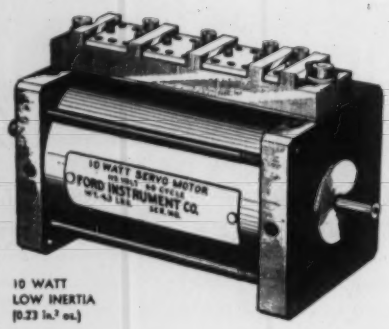
620 NO. LAKE AVE. PASADENA 4, CALIFORNIA

DIFFERENTIALS

3/16" 1/4" 5/16"

Precision Plus!





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LOW INERTIA
(0.23 in.² oz.)

LOW INERTIA SERVO MOTORS

Descriptive Literature on Request

FORD INSTRUMENT CO.
DIVISION OF
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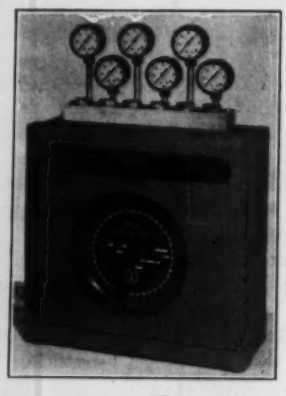
31-10 THOMSON AVENUE LONG ISLAND CITY 1, N. Y.

INTEGRATORS ESTABLISHED 1915

COSTS TOO HIGH?

ASK OUR SIC Representative How our **Automatic Equipment** Engineered to fit YOUR PROBLEM can SAVE YOU MONEY



We specialize in TIME CONTROL & SEQUENCE CONTROL DEVICES. Originally designed for rubber and plastics molders they are finding increasing use in CHEMICAL and OTHER PROCESSES for sequencing complex cycles with or without TIME. Without time they may be keyed to limits of position, temperature or other measurable values.

THE "PUSHBUTTON" CONTROLLER (Illustrated) is our MODEL PB-2. It is a HIGHLY FLEXIBLE example of our many adaptable TIME SEQUENCE devices.

SEELY INSTRUMENT CO., INC.
315 FOURTH ST., NIAGARA FALLS, N. Y.
Subsidiary of Aeronautical Manufacturing Corp.

Air Operated Hydraulic Valves to 7000 psi
And Valves for Heating & Cooling Services

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PRECISION

SURFACE CLEANING

Straight line production requires speed and flexibility in the cleaning of fine parts. The ENG-SOL Method of precision cleaning uses a high velocity spray of solvent and air—a single shot thoroughly cleans the surface—frees it of lint, fingerprints, lapping compounds or other contamination. Extremely safe—can not burn nor explode at any temperature.

Write for the illustrated booklet describing The ENG-SOL Method.

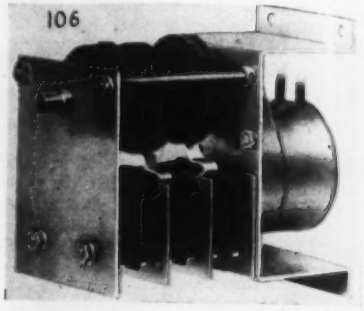
PASSAIC ANALYTICAL LABORATORIES, Inc.
228 Aycrigg Ave. Passaic, N. J.

Instrument is also suited for use in factory production lines. For permanent industrial applications, all-metal "WS-18A Panel Adapter" is available as an accessory to permit mounting portable instrument into standard 19-inch relay racks.—*Tube Dep't, RCA Victor Div., Radio Corp. of America, Camden, N. J.*

Mention No. 549 when filling out card

Cycle Timers

New "Type CF3" single or multi-contact cycle timers control automatically a one, two, three or four circuit

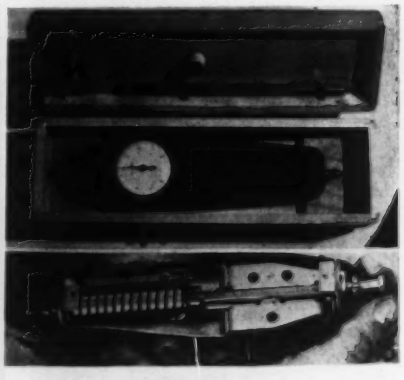


operation in a predetermined timing sequence to operate motors, valves, signals, etc. Timer consists of maker's synchronous motor with single or multiple cams operating an enclosed dust-proof snap-action switch. Available in 27 different time ranges, from one rev. in 10 secs. to one rev. in 24 hours, "CF3" timer can be supplied, on request, with a knob that allows timer to be started manually so that it will complete one operation and stop. A wide range of motor speeds makes unit adaptable to almost any cycle arrangements.—*R. W. Cramer Co., Inc., Centerbrook, Conn.*

Mention No. 550 when filling out card

Force Indicator

New force indicator for designers and engineers utilizes a precision compensated spring system to give easy force measurements accurate to 0.5 percent at full scale of dial indicator. Spring system is composed of three groups:



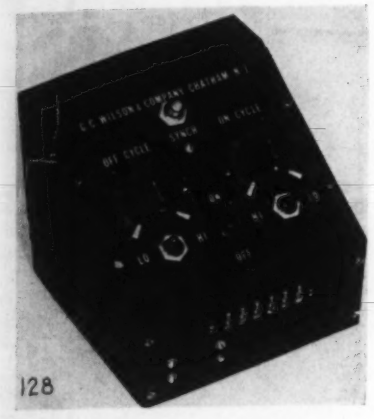
(1) main compression spring, (2) compensating extension spring and (3) load-transmission rod-centering springs and springs internal to dial indicator. Force is applied to system through a load transmission rod. Movement of this rod deflects compensated spring system. This deflection is measured by a low-friction dial indicator. Accurate force indica-

tions (spring gradient) are possible because (1) relationship between force and spring displacement is linear throughout dial range, (2) gradient of spring system is made with an accuracy of 0.2 percent and (3) friction is virtually eliminated. Instrument is shaped for easy one-hand operation. Six stainless steel force-transmission rod fittings give it a wide range of usefulness. Currently available unit has a 10-lb. capacity.—*Hunter Spring Co., Lansdale, Pa.*

Mention No. 551 when filling out card

Repeat Cycle Timer

New repeat cycle timer for refluxing, spot-welding, sign flashing, photo finishing and similar operations, employs



a vacuum-tube circuit to provide timing intervals by charging a resistance-capacitance network. One cycle initiates the second without further adjustment or manual operation. On-off cycles are infinitely variable between these ranges: On, 0.2 to 200 sec.; off, 0.1 to 60 sec. D-p., d-t. contact rated at 10 amps, 110 volts or 2 amps, 460 volts.—*G. C. Wilson & Co., Chatham, N. J.*

Mention No. 552 when filling out card

Thermal Switch

New "Microsen" thermal switch operates from thermocouple input to signal temperature variations in heating proc-

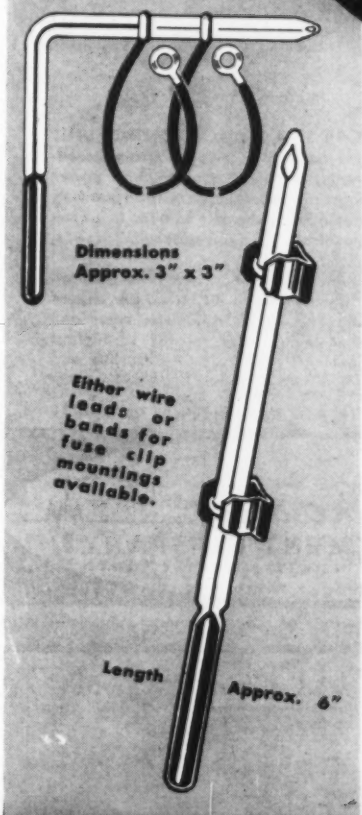
esses, and can be employed with valves, warning signals, motors, etc. Signal output is by electrical relay for on-and-off switching at 10 amps., 115 volts, a.c., or 32 volts d.c. Available in four temperature ranges from 100 to 2,000 deg. F. A knob and pointer on case indicates temperature setting. Operating accuracy

ASICO

THERMOSTATIC TEMPERATURE CONTROLS

They Act with Accuracy

(WITHIN A FRACTION OF A DEGREE)



ASICO thermostats are manufactured to customers' specifications within the normal range of mercury thermometers.

As the relays used with these thermostats are important to the proper functioning of the control, we have developed a special line of relays that are thoroughly dependable. With ASICO thermostats and these pre-tested relays, we can guarantee precise performance to the fraction of a degree.

Write for Bulletin 52

These straight or angle types are stocked ready for immediate delivery, with the exception of their final calibration to the desired temperature.

SPECIAL TYPES and tolerances to your specifications will receive prompt attention.

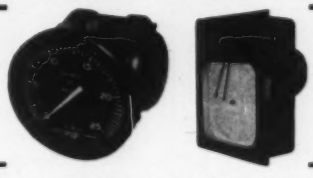
ACCURACY SCIENTIFIC INSTRUMENT CO.

2903 NO. 12TH ST., PHILA. 33, PA.

All Types of Thermometers and Hydrometers Made to meet your particular specifications and our exacting standard of accuracy.

NEW BARTON *FLOW METERS*

MODEL 200 DIFFERENTIAL PRESSURE INDICATOR



MODEL 202 DIFFERENTIAL PRESSURE RECORDER

For the first time, long desired operating characteristics of the actuating element in flow meters has been achieved by Barton Instrument Company.

Stainless Steel Rupture-Proof Bellows • Torque Tube Drive • Self Venting or Draining Actuating Unit • Removable Pressure Chambers • Differential Range: 0-20 W.C. to 0-300 W.C.

Write for Preliminary Data Sheets 200-1 and 202-1

BARTON INSTRUMENT CO.

3502 UNION PACIFIC AVE., LOS ANGELES 23, CALIF.

Strain Recording Equipment

The type MRC-15 STRAIN GAGE CONTROL UNIT and the type S8-B OSCILLOGRAPH make up a complete strain recording laboratory. The MRC-15 contains complete equipment to power strain gages and to drive oscillograph galvanometers for recording from static strain to a frequency of 5000 cycles per second. It is complete with strain gage balancing controls, precision calibrating device, and power supply equipment.

The S8-B, with 12 to 48 elements, is a highly-refined general-purpose oscillograph with chart speeds of ⅛ to 40 inches per second designed to accommodate a wide range of galvanometer types and characteristics. Precision optical system insures records of highest accuracy and quality. Many refinements contribute to versatility and convenience.

Write for Technical Bulletins

For the MRC-15, Bulletin No. SP-195H • For the S8-B, Bulletin No. SP-165H

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TEST YOUR MAGNETIC CIRCUITS

RAWSON FLUXMETER TYPE 504

The only portable fluxmeter available which returns rapidly to zero when a single button is depressed. Simple and fast in operation. Convenient and light in weight.

Not limited to a single type of measurement. Has universal application for laboratories or production. Measures strength of magnets and electromagnets, permeability and hysteresis loops for iron and steel, total flux lines in circuit, flux lines developed in air gap, etc.

Has a mechanical clamp to protect the pivots and jewels when in transit.

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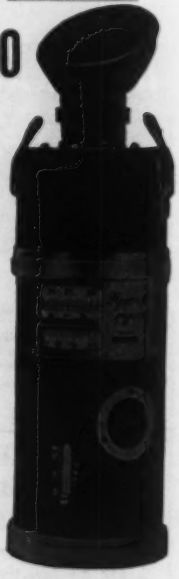
CHICAGO LOS ANGELES

The *Accurate* Way to Measure Extreme Temperatures *at a glance*

The Simplified PYRO Optical Pyrometer



SELF-CONTAINED. No correction charts, no accessories, no up-keep. *Direct-reading.*

ACCURATE. Permits *close* and *rapid* temp. *determination* — even on *minute spots, fast-moving objects, smallest streams.* ("Special Foundry Type" and "Triple Range" also have RED Correction Scale for determining *true spout* and *pouring* temps. of molten iron, steel in the open.)

LIGHT IN WEIGHT — Only 3 lbs. complete. Handy.

PROVED IN USE—Foundrymen all swear by it.

Stock Ranges 1400°F. to 7500°F.

Write for FREE Catalog No. 80—also catalogs on other PYRO Pyrometers

THE PYROMETER INSTRUMENT CO.
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BERGENFIELD 4, NEW JERSEY
In Canada, Sales and Repair Laboratory:
Dominion Flow Meter Company Limited
Toronto and Montreal

is said to be 2 percent, and safeguards are included to open relay in case of failure of any part. Instrument compensates for temperature variations from 60 to 140 deg. F. and operates under line voltage fluctuations of 95 to 130 volts.—*Manning, Maxwell & Moore, Inc., Bridgeport 2, Conn.*

Mention No. 553 when filling out card

Tension Scale

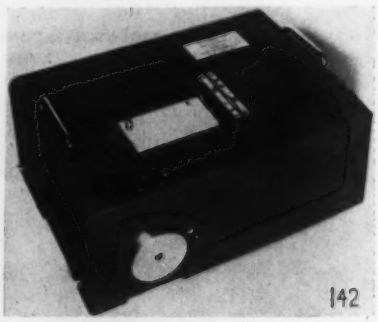
New scale for tension testing is of push-or-pull type with scale that can be inserted in small openings and is said

to be superior to single-action type. Rods are 6 in. long, threaded and detachable. Scale can be read in any position. Spring is treated alloy steel, shell is brass tubing and scale is nickel plated. Useful for measuring small torques, spring tension, breaker arm tension, etc. "Model 2-T" has 2 lb. capacity and is graduated in 0.25-oz. steps. "Model 5-T" has 5 lb. capacity, graduated in 1-oz. steps. "Model 20-T" has 20 lb. capacity and is graduated in 4-oz. divisions.—*Pelouze Mfg. Co.*, 1218 *Chicago Ave., Evanston, Ill.*

Mention No. 554 when filling out card

Oscillograph Amplifier

New equipment for measuring and recording strains, vibrations, pressure, temperature, sound, geophysical prospecting, etc., includes: (1) New "Model RO2B" oscillograph (illustrated), a direct-reading instrument with twin



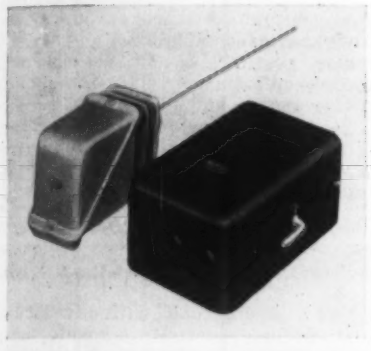
recorders, synchronous three-speed motor drive, and controls. Instrument will draw instantly graph of any two electrical signals within its range and display their wave-shape, amplitude and frequency. Incorporates new "Duratape" heat-sensitive paper on which sharp, legible lines are drawn without use of pen. Two parallel charts are each 40 mm. wide. Recorder sensitivity is 3 volts and 0.9 milliamps. per mm. Frequency response without amplifier is flat 0-70 cps. Damping may be off, linear or critical. Chart speeds are 12.5, 25 and 50 mm. per sec. (2) New dual amplifier designed especially to drive oscillograph

has two combination a-c., d-c. amplifiers with self-contained power supply. Metered d-c. square wave calibration pulse to both channels. Features are individual step attenuators, high-gain a-c. amplification and adjustable high-frequency boost. Square wave pulse of 1, 10 and 100 mv. is provided to give a direct calibration in mm. recorder deflections per mv. for a-c. or d-c. operation. As a-c. amplifier, instrument has frequency response of flat 0.1 to 5,000 cps., voltage gain of 75,000, and grid-to-ground impedance of 2 megohms. As d-c. amplifier, it has frequency response of 0 to 5,000 cps., voltage gain of 3,000 and 2 megohm impedance, grid to ground. Drift is less than 1 chart mm. per hour. —*Rahm Instruments, Inc.*, 12 *West Broadway, New York* 7, *N. Y.*

Mention No. 555 when filling out card

Gas Flame Safeguard

New model of combustion safeguard for ovens, kilns, boilers and other gas-fired equipment is comprised of flame

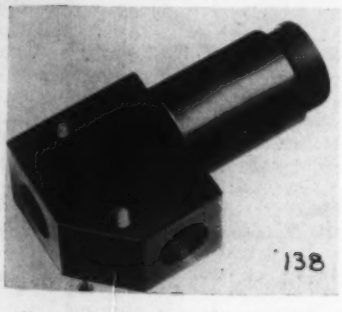


rod "Type 45JQ1" and control "Type 24QJ5." Flame rod, attached in heating chamber, "feels" flame and, if flame fails, signals to control which turns off fuel and sounds alarm. Instrument features fail-safe circuit with safety-start protection and ease of installation; is immune to moisture or electrical leakage. Available for 115 or 230 volt a.c. Ambient temperature is stated as 32 to 125 deg. F.—*Combustion Control Corp.*, 77 *Broadway, Cambridge* 42, *Mass.*

Mention No. 556 when filling out card

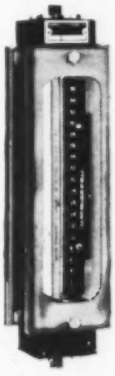
Solenoid-operated Valves

New group of small, light-weight, solenoid-operated valves for air or fluids, suitable for operation over an excep-



tionally wide range of temperatures includes "Model 10041," a normally-closed, two-way valve designed for continuous duty at ambient temperatures between minus 65 and plus 200 deg. F. It handles air or fluids at pressures up

A handy rotameter kit for Laboratory and Pilot Plant



Our Multi-Range Flow Rate Kit gives 19 gas ranges from 5 to 10,500 cc/min., and 19 liquid ranges from 0.1 to 325 cc/min. Higher ranges can also be obtained if necessary. This Kit is now an important research adjunct in hundreds of laboratory and pilot plants. Write for Bulletin No. 5.

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PRECISION
Glass Apparatus

. . . FOR YOUR INSTRUMENTS

WITH precision accuracy and matchless dependability our "glass-masters" are prepared to fabricate any specific glass apparatus requirement for the instrument industry. We are actively engaged in the manufacture of scientific glassware, and are equipped to supply your "tailor-made" needs swiftly, efficiently and at low cost.

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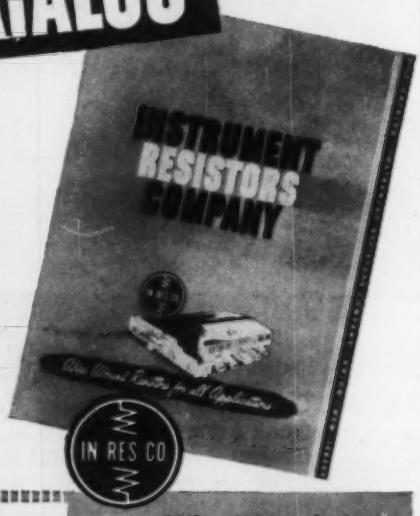
when you need resistors—

IT WILL PAY YOU TO CONSULT THE NEW

IN-RES-CO CATALOG

Included are complete descriptions and specifications on wire wound resistors of all types and sizes. Each is precision wound to close tolerance, and many feature special moisture-proofing to assure proper functioning under severest climatic conditions. INRESCO Resistors —available for IMMEDIATE DELIVERY—are supplied in standard or custom types to meet the most unusual design or operational requirements, and are offered at prices that benefit from mass production facilities. A copy of the new INRESCO catalog will be helpful; write for it today. Prices, samples and estimates promptly on other than standard resistors.



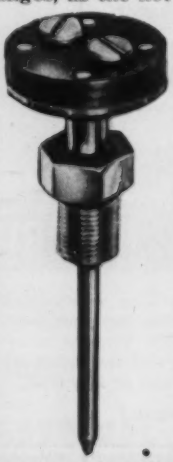
INSTRUMENT RESISTORS COMPANY
1036 COMMERCE AVE., UNION, N. J.

Wire Wound Resistors for Every Use in Electronics and Instrumentation

A QUICK SIGNAL . . .

That's what you want from a thermocouple

THERMO'S improved Protected Thermocouples respond rapidly to any temperature changes, as the hot junction is an integral part of the thin-walled protection tube.



Used extensively for pilot plants and processes requiring frequent temperature checking, these Iron Constantan thermocouples have either Quick Coupling Plug or Screw Connection; 3/16" stainless protection tubes and ⅛" N.P.T. brass fittings. Immersion lengths from 1" to 3". Chromel Alumel or Copper Constantan also available.

Write for our Catalog F.

Thermo ELECTRIC CO.
FAIR LAWN, N. J.

—MICO—

2 & 3-DIMENSIONAL

ENGRAVER

Permits accurate reproduction of three-dimensional master on any of four reduction ratios.

Catalogue on request

MICO INSTRUMENT CO.
86A TROWBRIDGE STREET
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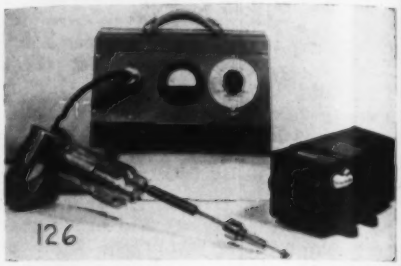
to 12 psi. Other models, both two-way and three-way, are capable of handling fluids or gases at pressures up to 50 psi. and can operate intermittently at temperatures as high as 450 deg. F.—*Carma Mfg. Co.*, 2401 *E.* 103*rd St., Los Angeles* 2, *Calif.*

Mention No. 557 when filling out card

Tube Expander

New electrically-controlled tube expander capable of precision work even in inexperienced hands, is said to in-

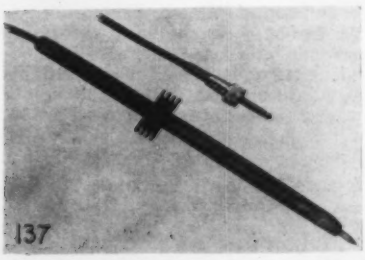


crease output as much as 50 percent, eliminates over-expanding and reduces erosion possibilities. Unit consists of control, automatic voltage regulator, driving motor and expander. Operates on 115 volts, 60 cycle a.c., and has shut-off which can be set at any desired value.—*Crane Packing Co.*, 1800 *W. Cuyler Ave., Chicago* 13, *Ill.*

Mention No. 558 when filling out card

High-voltage TV Probe

New "Super Probe" with any vacuum tube voltmeter permits accurate measurement of high voltages in television sets, X-ray machines and other High Voltage apparatus. Improved design makes that portion of probe relatively



cold where it is gripped by hand. Long slenderized hot portion of probe is separated from handle by heavy duty labyrinth barriers. It is easy to get into tight places that present a problem to bulky probes. Multipliers extend range of vacuum tube voltmeters times 100. Probes are rated for use up to 30,000 volts—are guaranteed up to 35,000 volts and have an extensive safety factor. They are supplied with proper co-ax or other connector ready to attach to individual instrument specified.—*Reiner Electronics Co., Inc.*, 152 *West* 25 *Street, New York* 1, *N. Y.*

Mention No. 559 when filling out card

Microwave Dielectrometer

CORRECTION: March issue, page 241, name of manufacturer should be Central Research Labs., not General Research Labs.

Counts to 10,000 Turns per Minute

Clipper Coil Winding COUNTER

also ideal for other high speed Revolution Counting

Brings counter *close to coil* for *precision winding at high speed.* Subtracts turns removed. Quick, one-motion reset. Gears hobbed on own shafts. Extremely long life. Many other features. Prompt shipment. Thousands in use. Send for Catalog or order sample on approval.

Production Instrument Company

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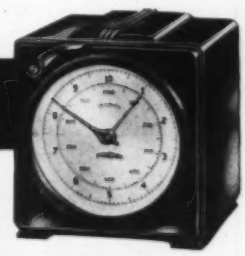
Representatives in Principal Cities

Standard

TIMERS



WORLD'S MOST ACCURATE AND RUGGED TIME MEASURING INSTRUMENT. CAN BE MANUALLY OR ELECTRICALLY OPERATED. FURNISHED IN PORTABLE CASES OR FOR PANEL MOUNTING.

T-1

Model	Reads	Totalizes	Accuracy
S-100	1 5 sec.	6000 sec.	±.02 sec.
S-60	1 5 sec.	60 min.	±.02 sec.
SM-60	1 100 min.	60 min.	±.02 sec.
S-10	1 10 sec.	1000 sec.	±.02 sec.
S-6	1 1000 min.	10 min.	±.02 sec.
S-1	1 100 sec.	60 sec.	±.01 sec.
MST	1 1000 sec.	.360 sec.	±.001 sec.
MST-500	1 1000 sec.	30 sec.	±.001 sec.

WRITE FOR BULLETIN 153

also Standard Chrono-Tachometers • Standard Custom-built Laboratory Test and Distribution panels

THE Standard Electric Time Co.

93 Logan Street STANDARD FOUNDED 1884 **Springfield, Mass.**

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PAPER WORK, HEADACHES AND INSTALLATION PROBLEMS

of
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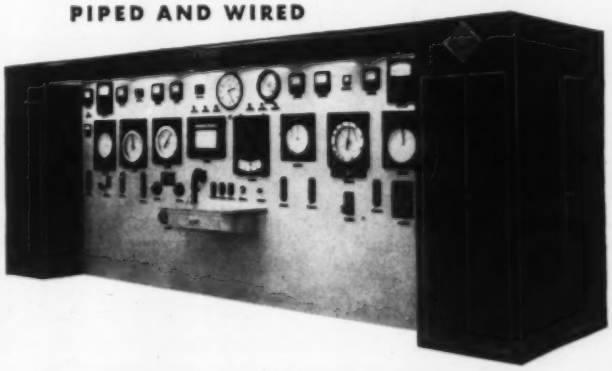
PURCHASING
and
FIELD ASSEMBLY

SPECIFY **PANELLIT**

FOR
COMPLETE,
PRE-FABRICATED
INSTRUMENT AND CONTROL PANELS
PIPED AND WIRED



Complete installation can be *"packaged"* by Panellit, including the purchasing of all equipment in accordance with your specifications. Or, the instruments and controls can be furnished by you.

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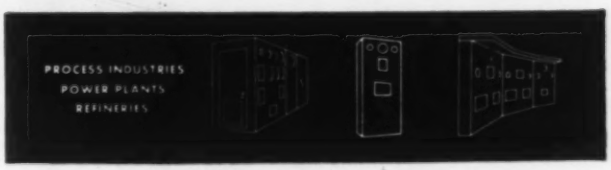

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INSTRUMENTS ON THE MARCH

Measurement *of* Proton's Magnetic Moment Will Improve Instruments *and* Servos

WASHINGTON, D. C.—The magnetic moment of the hydrogen nucleus, or proton, has been accurately determined in absolute units by H. A. Thomas, R. L. Driscoll, and J. A. Hipple at the National Bureau of Standards. The gyromagnetic ratio of the proton, from which the magnetic moment was obtained, has been accurately determined by measuring the magnetic field and radio frequency required for magnetic resonance absorption in a proton sample. This is the first precise determination of the proton moment in absolute units; all previous measurements approaching this precision have been made in terms of the relative values of other physical constants. The nuclear resonance method used in this work at the Bureau is a natural extension of basic work by F. Bloch and by Purcell, Torrey, and Pound.

This new measurement of the proton's gyromagnetic ratio also provides an accurate secondary standard for magnetic fields. In the past, laboratory measurements involving both magnetic and electric fields have been limited by the low accuracy of the magnetic measurements. Now the situation is reversed and magnetic fields can be measured more accurately than electric fields. This advance will be especially useful in the design and development of scientific and industrial apparatus employing magnetic fields.

The nuclear resonance techniques developed in the course of this work can be applied to good advantage wherever the strength of a magnetic field must be closely regulated. The problem of magnetic field measurement and regulation arises widely in the use of instruments—mass spectrographs, beta-ray spectrometers, etc.—and in industrial control equipment—servomechanisms and electromagnets.

Any application of the nuclear resonance techniques would make use of properties of the magnetic moment arising from the proton's intrinsic angular momentum, or spin. In the presence of a magnetic field, the proton can orient itself either parallel or antiparallel to the direction of the field (see Fig. 1). These two orientations then represent the alternative spin energy states for magnetically polarized protons. The parallel orientation is the normal state, while the antiparallel is the excited state, which is higher in energy by an amount that depends on the strength of the magnetic field.

Because of their magnetic moment and angular momentum, protons will precess around the direction of an applied magnetic field in the same way that a gyroscope will precess in a gravitational field. The rate of precession is independent of the proton's orientation. In a given magnetic field, a proton can reverse its spin orientation only by taking on or giving off energy at this one resonance frequency. Since magnetic resonance absorption is independent of atomic or molecular bonds, ordinary water can be used as a proton sample.

The frequency required for spin reversal involves the proton's gyromagnetic ratio, a fundamental physical property with a constant value. The magnetic resonance frequency and the magnetic field strength are linearly related by a rather simple equation.

If the value of the gyromagnetic ratio is known, the field can be determined from the radio frequency that produces spin transitions in the proton sample. Alternatively, the proton's gyromagnetic ratio may be determined from the values of the field and of the spin-reversal frequency which produce magnetic resonance. Since the spin transitions occur at ordinary radio frequencies for the usual values of magnetic field strength, resonance absorption is not difficult to observe.

A typical experimental set-up at the NBS includes a water sample placed in a magnetic field of 4700 gauss and surrounded by a small radio-frequency coil with its axis perpendicular to the magnetic field. Thus, if the coil is excited by a 20-megacycle signal, an r-f. field will be produced in the sample and protons in the normal spin state will absorb r-f. energy and shift to the excited state. A sensitive Q-meter can be used to detect the reduction in the Q of the coil resulting from this energy absorption by the nuclei. Energy absorption can continue to take place be-

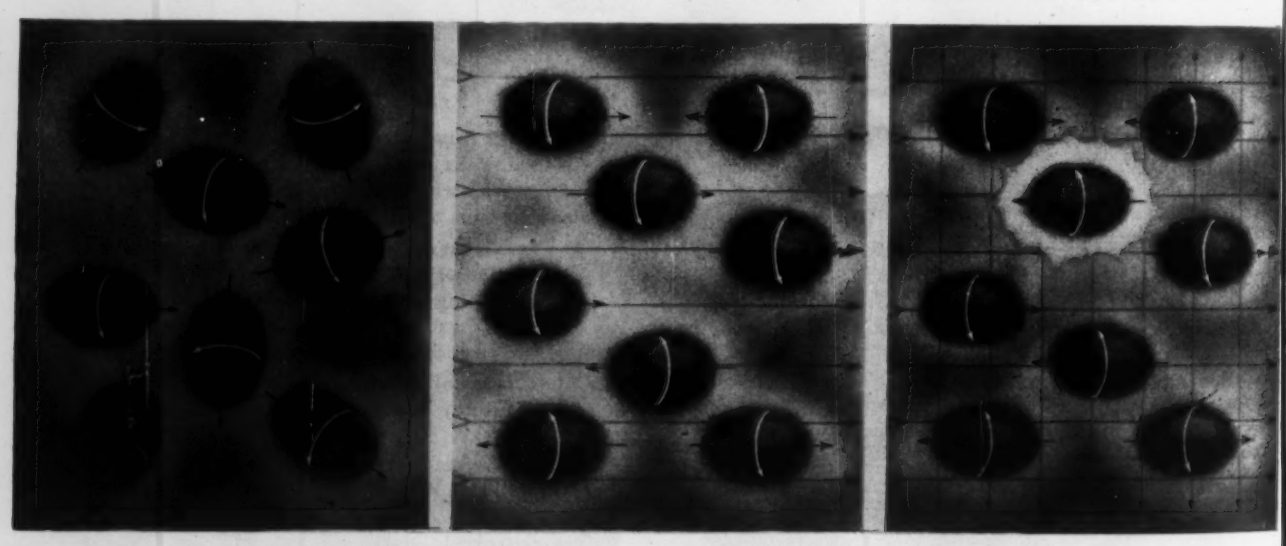


Fig. 1. SCHEMATIC OF PROTON'S MAGNETIC RESONANCE ABSORPTION.

In the absence of any electric or magnetic fields, the spinning protons, or hydrogen nuclei, are oriented in space at any instant in a completely random manner The direction of the magnetic moment is represented by a straight arrow on each proton. The curved white arrows indicate the direction of spin. Both magnetic moment and spin are fundamental physical properties of all nuclear particles.

In a steady magnetic field, most of the protons line up in the direction of the field (normal spin state), while some of them line up with their axes pointing in the opposite direction (excited spin state). The difference in energy between the normal and excited spin states depends on the strength of the magnetic field. Each proton will precess about the direction of the field at a rate that depends on the field strength.

If a radio-frequency field is superimposed on a magnetic field of the proper strength, some of the protons in the normal spin state will take on energy from the radio-frequency field and shift to the excited state. This process of taking on energy is known as nuclear resonance absorption. In a given magnetic field, a proton can reverse its spin orientation only by taking on or giving off energy at one resonance frequency.

cause protons in the excited spin state gradually return to the normal spin state by losing their energy thermally to the surroundings. This return to the normal spin state involves a relaxation time which depends on the kind of proton sample used.

If the value of the field at the sample is varied at an audio rate, the r-f. voltage across the coil will change sharply as nuclear resonance occurs. Resonance can then be detected without using a Q-meter since, if the voltage pulse from the coil is rectified and amplified, the resonance absorption line may be displayed as a stationary image on an oscilloscope screen. By including a differentiating circuit to obtain the time rate of change of the resonance pulse, the magnetic field strength can be regulated extremely closely through a power amplifier and feed-back circuit. A regulator of this kind at the NBS has given a magnetic field stability of two parts in a million for a change of one percent in main magnet excitation.

In order to measure the gyromagnetic ratio of the proton, the magnetic field of the large electromagnet was stabilized by this resonance method. The spatial distribution of the field was improved by shimming the magnet gap; the remaining field variations were then mapped to 1 part in 50,000 by probing the field with a resonance detector. With the field stabilized, the frequency of the r-f. voltage applied to the coil enclosing the proton sample was adjusted to produce magnetic resonance. The magnetic field strength was then determined to 1 part in 20,000 by measuring the force on a known length of current-carrying wire placed in the field. This wire was in the form of a nine-turn coil wound on the edge of a long rectangular glass plate with its lower end in the magnetic field. The plate was supported by an analytical balance so that the force resulting from the interaction of the coil current with the magnetic field could be accurately measured. The stray field at the upper end of the coil was reduced to zero by a pair of Helmholtz coils and, since the long parallel sides of the coil did not contribute any vertical force, the chemical balance measured only the force acting on the part of the coil along the lower end of the plate. The method used in the measurement of the magnetic field is similar to one employed previously by Briggs and Harper.

The frequency of resonance absorption was measured to a few parts per million by heterodyning the r-f. generator supplying the resonance probe against the standard frequency broadcasts from WWV. These measurements of radiofrequency and magnetic field are then all that is required to establish the value of the gyromagnetic ratio of the proton. Taking into account the precision of each measurement, this value turns out to be 26,752 plus-or-minus 2. This accuracy of one part in 13,376 is seventy times better than the best previous absolute measurement. The value for the magnetic moment of

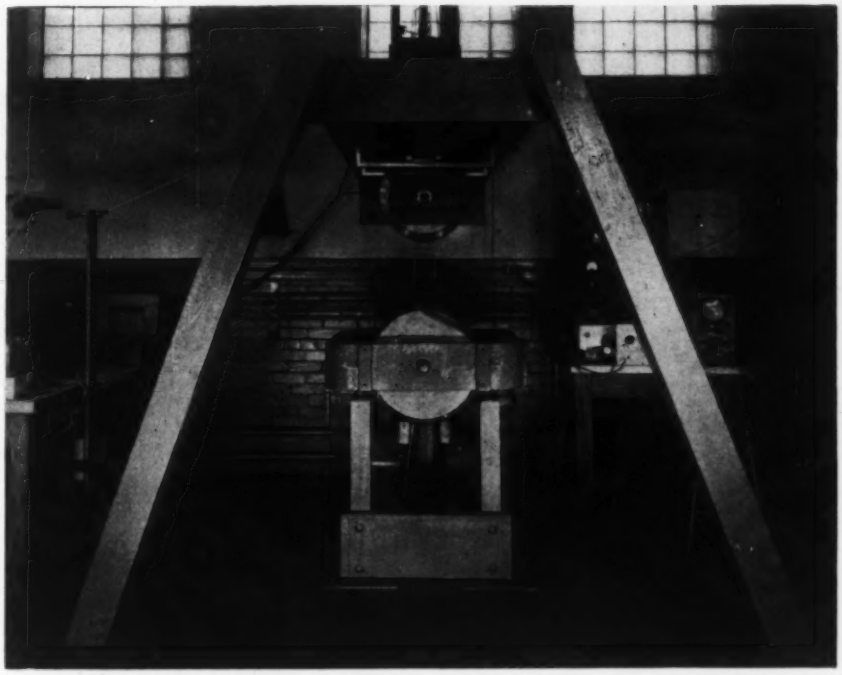


Fig. 2. General view of the experimental set-up for the absolute measurement of the proton magnetic moment in the Atomic Physics laboratory at the NBS. The main framework provides a rigid support for the precision chemical balance (top) which measures the force on the current-carrying coil that hangs between the poles of the large electromagnet to determine the strength of the magnetic field. A rectangular glass plate is suspended from the balance; its lower end in the space between the pole pieces of the magnet. Nine turns of specially drawn copper wire are wound around the outer edge of the plate in parallel guide grooves. Electrical measuring instruments (left) are used to determine the coil voltage and current with extremely high accuracy. The electronic equipment (at the right rear) consists of a 20-megacycle signal generator, power supplies, and servo circuits to regulate the magnetic field strength and to detect resonance in the proton sample. A trace of the resonance absorption line appears on the oscilloscope screen when the r-f. circuits have been tuned to resonate with the proton absorption frequency. The radio receiver (extreme right) calibrates the r-f. signal against standard frequency from NBS station WWV.

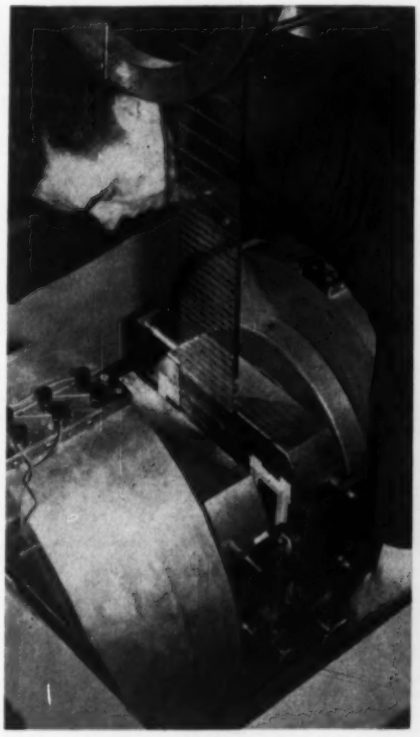


Fig. 3. Top view of magnet assembly showing large cylindrical metal cases enclosing the main field coils. Dr. Thomas is shown adjusting the position of a nuclear resonance detector to plot the strength of the magnetic field. The proton sample itself (ordinary water) is enclosed in a glass ampule between the local field coils mounted on the tip of resonance detector at the edge of the pole pieces.

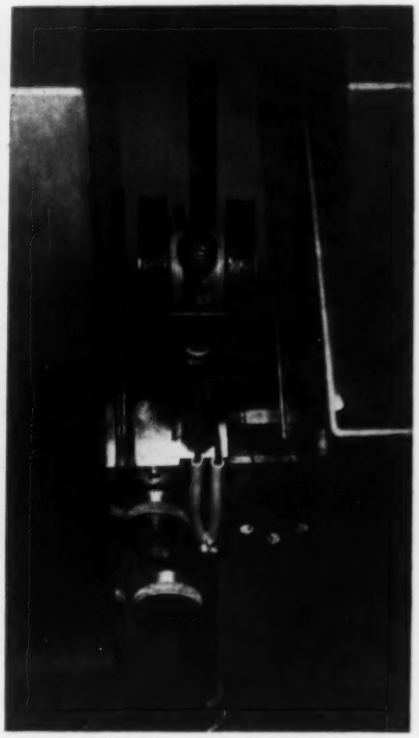


Fig. 4. Close-up of the nuclear resonance probe in the gap between the pole pieces of the magnet. The proton sample is ordinary tap water enclosed in a glass ampule surrounded by a small 20-megacycle radio-frequency coil. The two narrow coils at each side of the sample are used to vary the local magnetic field. A rack and pinion arrangement allows the resonance head to be moved to any desired point in the magnet gap.

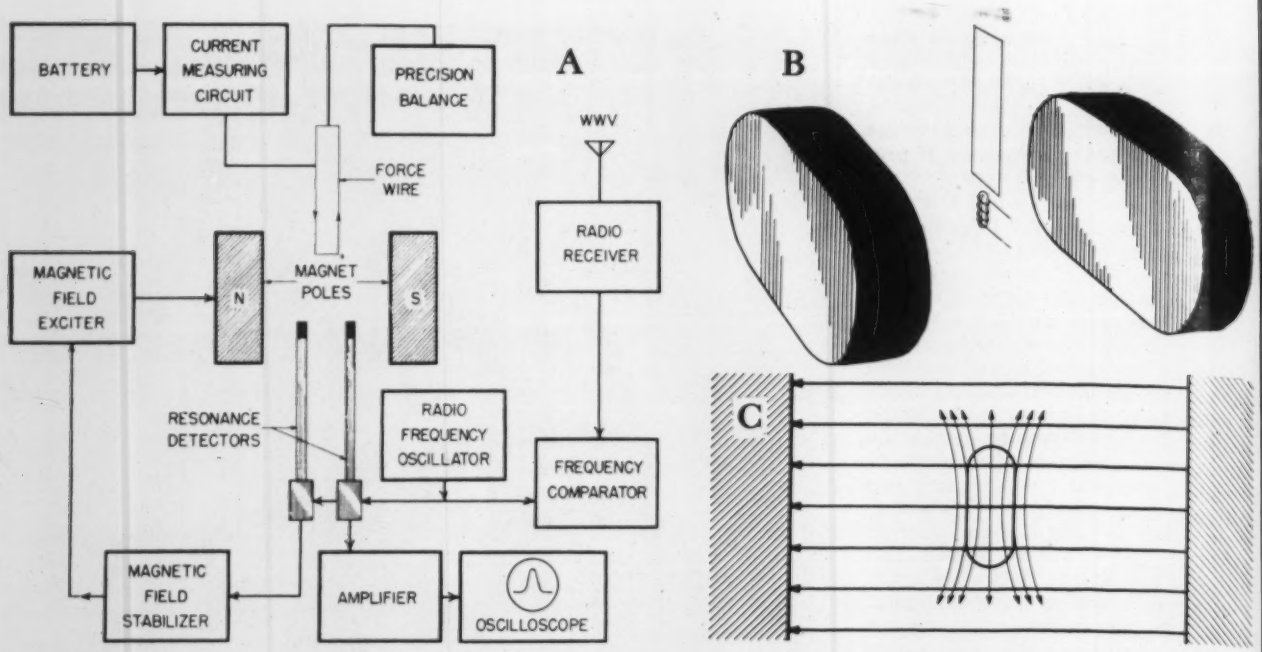


Fig. 5. (A) Complete block diagram of the experimental instrumentation at the NBS for the determination of the magnetic moment of the proton. (B) Perspective view showing general arrangement of the two pole pieces of the magnet, the force wire, and the proton sample surrounded by an r-f. coil. (C) Representation of the field conditions in the vicinity of the proton sample, showing magnetic lines of force (heavy straight lines) produced by the electromagnet together with the r-f. field (light curved lines) of the 20-Mc. coil.

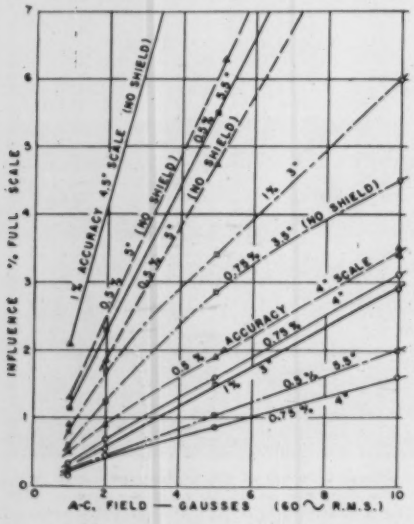
the proton, in absolute units, is 1.41000 $\times 10^{-23}$ gauss cubic centimeters and is accurate to 1 part in 6000. Work under way will extend this accuracy.

The Bureau's research on the absolute proton moment makes it possible to examine the accuracy of other physical constants whose values depend on magnetic field measurements. In a recent experiment reported by Taub and Kusch of Columbia University, the nuclear g-factor of the proton was measured by the molecular beam method relative to the atomic g-factors of certain alkali atoms. The new value of g and the new value of the proton's gyromagnetic ratio combine to give a new value of the electron charge-to-mass ratio: 17,587,800 electromagnetic units per gram, accurate to 1 part in 11,000—the highest accuracy ever attained.

Performance *of* Portable Electrical Instruments *in* Magnetic Fields

WASHINGTON, D. C.—Most portable electrical instruments depend upon an internal magnetic field for their operation. A stray external field may however modify this internal field and make the instrument read incorrectly, particularly when the external field is not taken into account. To determine the extent of such fields and how best to minimize their effects on voltmeters, ammeters and wattmeters, an investigation of a representative group of commercial portable instruments was undertaken by A. E. Peterson and associates of the National Bureau of Standards. A brief study was also made of the stray fields about some of the more common kinds of laboratory apparatus.

For this investigation magnetic fields of known magnitude, direction, and phase angle were set up about the test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A-C. FIELD — GAUSSES (60 ~ R.M.S.)
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0.5 % ACCURACY 4" SCALE
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0.75 % 4"

Fig. 1. Graphs showing effect of magnetic fields on moving-iron instruments. Note that of 11 instruments examined, seven exhibited field influences within their accuracy figures in a 1-gauss field, four in a 2-gauss field, and none in a 5-gauss field.

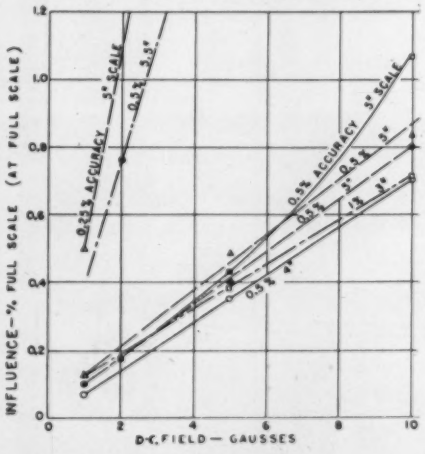

Fig. 2. Effect on 7 permanent-magnet moving-coil instruments. Two—having unshielded low-coercivity magnets—were affected in fields of less than 1 gauss by amounts comparable to their accuracy; the other five—with high coercivity magnets or low-coercivity magnets combined with good shielding—behaved similarly and withstood 5-gauss fields or stronger without influences greater than their accuracy figures.

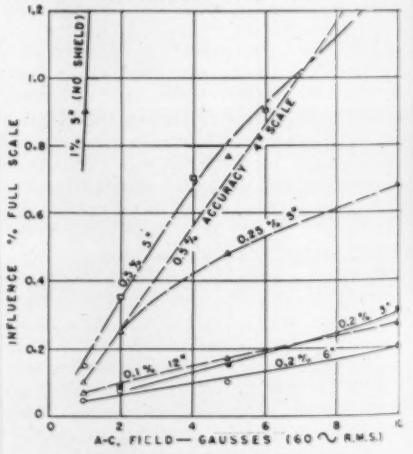

Fig. 3. Graphs showing the effect of magnetic fields on electrodynamic instruments. Note that of 7 electrodynamic instruments investigated, one—unshielded in a 1-gauss field—showed a field influence of 0.9 percent, nearly equal to its 1 percent accuracy figure; at 2 gausses the remaining six showed field influences less than their accuracy figures; while two of the six still met this qualification in a 5-gauss field.

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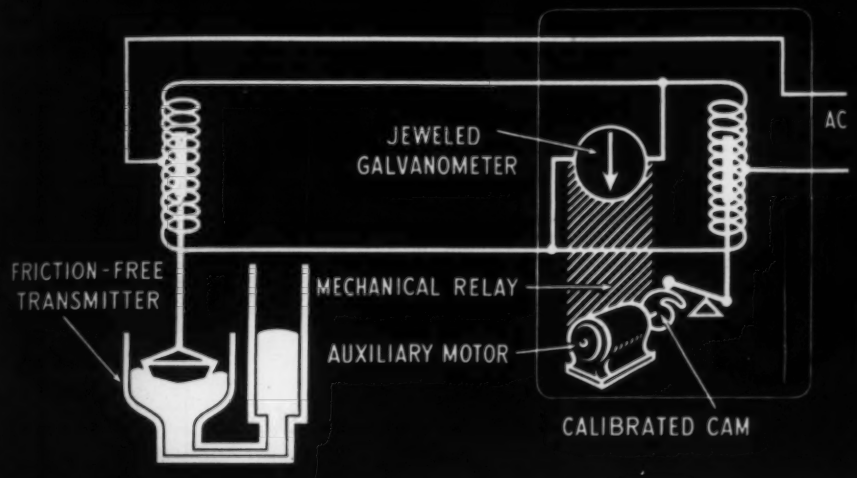
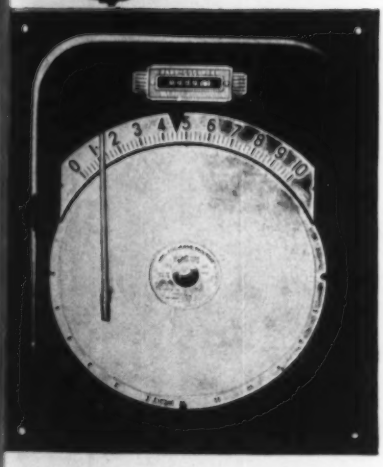


the measuring circuit does none of the operating work



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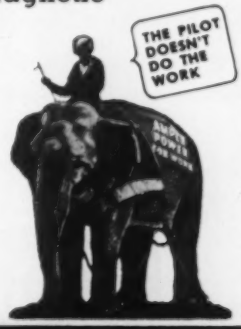

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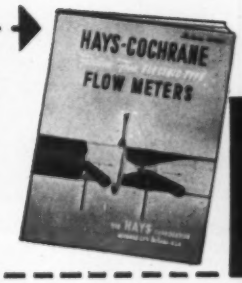

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instruments by means of a pair of Helmholtz coils and suitable auxiliary apparatus. These coils — a common means of securing a uniform field in a large space—consisted of two matched circular coils one meter in diameter and spaced axially one-half meter apart. A field uniform to within 3 percent was thus established in a volume large enough to accommodate the largest of the test instruments, 15 inches by 15 inches by 5 inches. The coils were gimbal-mounted, allowing the axis to be swung to any desired azimuth and elevation. (See Fig. 4).

Auxiliary instruments, well-shielded and of high quality, were used as comparison standards. Placed well away from the Helmholtz-coil field, they were read with a microscope.

Twenty-five instruments were tested in fields ranging from 1 to 10 gausses. In each case the direction of the field and the phase angle with respect to the current in the test instrument were adjusted to produce the maximum effect on its deflection. The change in reading produced by a 180-degree reversal of the field was noted for each field-strength value. One-half of this change, measured in divisions and expressed as a percentage of full-scale reading, was taken as the value of the magnetic-field influence.

In summarizing the results of the tests, the magnetic-field influence was compared with the manufacturer's figure for the stated accuracy of the instrument. The latter figure, an index of the quality of the instrument, does not generally take account of its susceptibility to magnetic fields; for an unshielded instrument especially, the accuracy figure may be completely negatiated by the stray-field influence even in very moderate fields.

On this comparison basis an analysis of test results revealed the following:

(1) Of eleven moving-iron-type instruments tested, seven exhibited field influence values within their accuracy figures in a 1-gauss field; in a 2-gauss field, four met this qualification; while none did in a 5-gauss field.

(2) Of the seven permanent-magnet moving-coil instruments tested, two—having unshielded low-coercivity magnets—were affected by amounts comparable to their accuracy figures when subjected to fields of less than 1 gauss; and the other five—with high coercivity magnets, or low-coercivity magnets combined with good shielding—behaved in a similar manner and could withstand 5-gauss fields or stronger without showing field influences greater than their accuracy figures.

(3) Of seven electrodynamic instruments investigated, one (unshielded) in a 1-gauss field showed a field influence of 0.9 percent, nearly equal to its 1 percent accuracy figure; at 2 gausses the remaining six showed field influ-

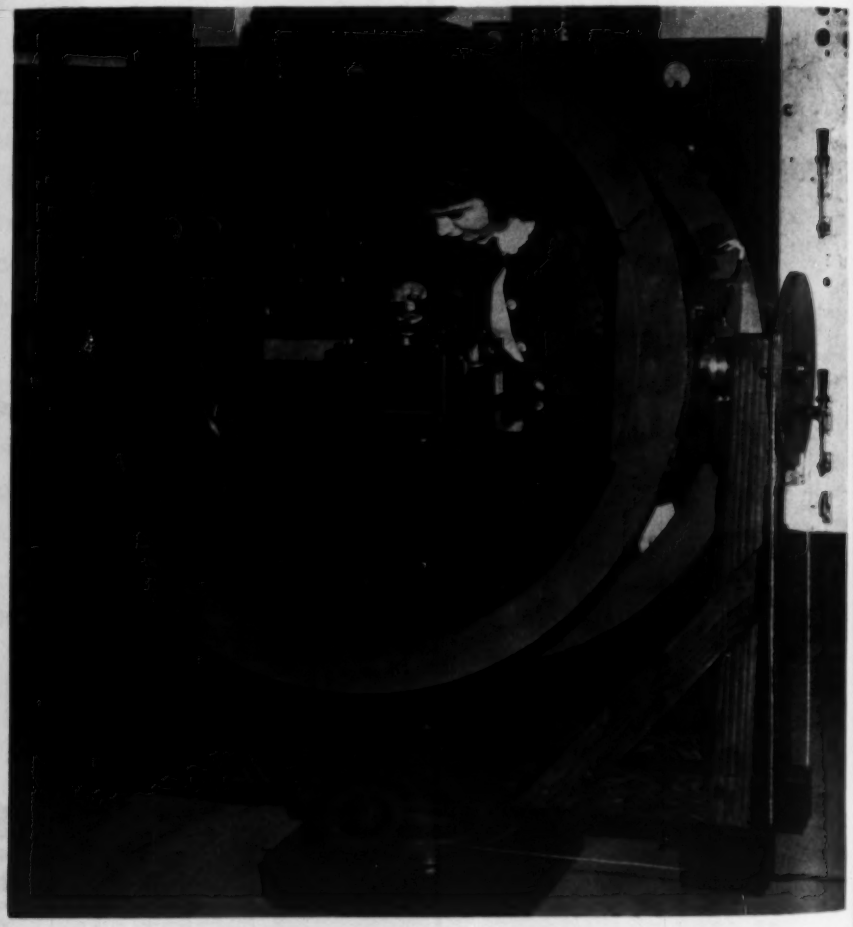

Fig. 4. Pair of matched circular Helmholtz coils used to set up magnetic fields of known magnitude, direction, and phase angle. A field uniform to within 3 percent was established in a volume large enough to accommodate the largest of the test instruments (note instrument in test position).

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ences less than their accuracy figures; while two of the six still met this qualification in a 5-gauss field.

All data apply to the top scale points; the corresponding field influence percentages for the lower scale points depend on the type of instrument. For "square-law" instruments such as the moving-iron type and the electrodynamic voltmeters and ammeters, this percentage remains essentially constant over the scale. With permanent-magnet moving-coil instruments having a linear scale, the field influence is proportional to the deflection. Thus for an influence of one percent at top scale, the figure would be one-half percent in the same field at half scale.

The instrument itself (for most types) may be used to check the presence of harmful stray fields if its supply is sufficiently steady. This is done by noting any change in reading of the instrument for positions 180 degrees apart, for a number of orientations. Such a test must be used with caution since, for some orientations, changes resulting from unbalance or displacement of the moving system might mask the field effects. Except for permanent-magnet moving-coil instruments (and for moving-iron a-c. instruments in direct fields) such a check may also be made by reversal of the leads to the instrument. If the instrument cannot be located outside of a disturbing field, an orientation may be found such that a 180-degree change in position causes a minimum change in reading.

In making a laboratory survey of stray alternating fields, Bureau engineers used a small search coil whose pickup voltage was measured with an electronic voltmeter. The magnetic field was readily computed from this voltage, the frequency, and the area-turn constant of the coil. A small commercial gaussmeter was used for direct fields.

Of the laboratory apparatus surveyed, only a few items showed fields as large as one gauss at distances of 10 centimeters. These included the larger rotating machines, a 1-kva. voltage-stabilizing transformer, a 2- and a 7-kva. adjustable-ratio autotransformer, and some of the tubular rheostats wound on magnetic tubes or having magnetic tie or slider rods. The stray fields about the adjustable-ratio autotransformers were found to depend greatly on the loading and on the proportion of the winding tapped off. For such apparatus, spacings of one-half meter were generally adequate to reduce the stray-field value to well below one gauss.

The Bureau's investigations show in general that the chief factor regarding the effect of stray fields on instruments lies in failure to recognize such effects and in not taking steps to avoid them. In addition, conductors carrying heavy currents may also be a disturbing source of stray-field trouble in the laboratory. Placing such conductors as close to one another as possible, twisting them together and otherwise avoiding open loops, will usually minimize their stray fields.

Fig. 1. Over-all view of the recording magnetometer. Dr. D. S. Miller is shown positioning a sample in the specimen holder.

Autographic Torque Magnetometer Aids Selection *of* Special-purpose Steels

NEW YORK, N. Y.—A new electromagnetic instrument that measures and records automatically the mechanical torque exerted by a uniform magnetic field on a circular disk of sheet iron or steel to determine uniformity of its magnetic properties has been developed by Dr. Donald S. Miller, a staff scientist at the Research Laboratory, United States Steel Corporation of Delaware, in Kearney, N. J. The recording torque magnetometer uses flat steel samples about the size of a quarter dollar. It records a curve in six minutes.

Two typical practical applications in which measurements of this kind have proved useful are: (1) in testing improved high-grade silicon steels for electrical transformer cores, in which superior magnetic properties are desired in the rolling direction; and (2) in controlling production of tin-plate with uniform drawing properties for the manufacture of such products as bottle caps. In the latter case, magnetic anisotropy, as indicated in the torque test, gives a clue to the amount of preferred orientations present in the crystallographic structure. This, in turn, indicates the extent of the directionality to be expected in the mechanical properties. Hence, the recording magnetometer provides a new tool that will be valuable in studying drawing qualities of steel used in such applications as automobile fenders and bodies.

Although measurement of magnetic torque is not a new development, in the present instrument the torque exerted on the disk is converted by a resistance strain gage to a small d-c. voltage that is fed to a strip-chart voltage recorder of the proper sensitivity. The sample disk is rotated about an axis perpendicular to its plane by a synchronous motor driving through reduction gearing. The recorder chart also is driven by a synchronous motor, so that there

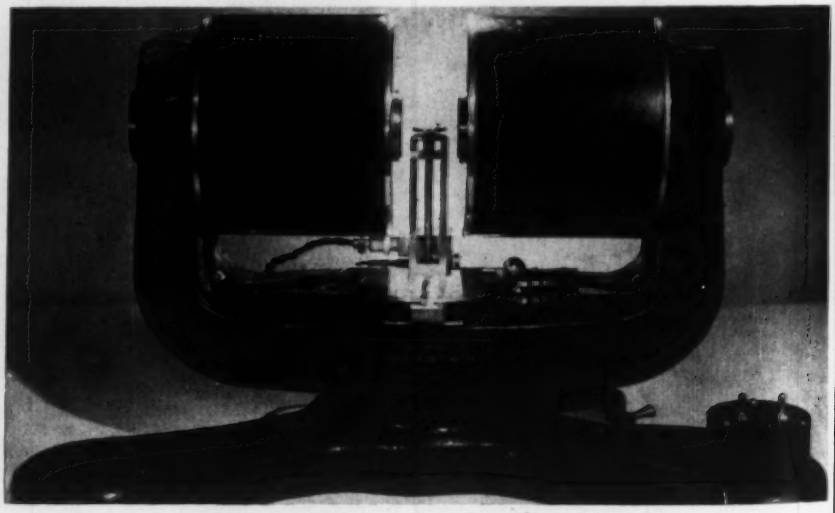

Fig. 2. Close-up view of torque magnetometer

is a definite relation between the angular rotation of the disk and the movement of the chart paper.

As the disk rotates, the torque varies and the pen in the recorder travels crosswise on the chart in accordance with this variation. By use of the proper conversion factor, the voltage recorded on the chart becomes a plot of torque versus angle of orientation of the disk in the magnetic field, using the rolling direction as the reference.

A view of the complete installation is shown in Fig. 1. The unit on the table at the right is the torque magnetometer, consisting of the electromagnet, the torsion gage, the specimen mounting, and the drive which rotates the specimen in the magnetic field. The cabinet at the left contains the recorder and the control equipment necessary for operating the instrument. The controls on the top panel permit the operator to vary the sensitivity of the resistance gage for selection of the conversion factor to alter the torque scale on the chart for different types of material, and to compensate for different thicknesses. Controls on a bottom panel in the cabinet (not visible in Fig. 1) permit adjusting the current flowing through the magnet windings to regulate the strength of the magnetic field.

A close-up view of the torque magnetometer is shown in Fig. 2. The magnet is of rather conventional design. The air gap, in which the specimen is mounted, is 1.75 inches. With 2.5 amperes (at 120 volts) through the magnetizing winding, the field strength at the center of the gap is about 4000 oersteds. The torsion gage, with specimen mount, is that part of the instrument shown between the two magnet coils. It is mounted on a dial plate, 6 inches in diameter, whose periphery is graduated in degrees of angle. This dial plate is attached to a shaft which passes through the base of the magnet, connecting to a gear train housed in the pedestal.

The synchronous motor which drives the gear train is mounted on the back of the base. The thumb-lever visible on the lower right of the base operates a clutch which disconnects the gear train from the motor shaft to permit free rotation of the dial plate and torsion gage. The cable visible under the left-hand magnet coil connects the strain gage with its direct-current supply circuit and with the measuring circuit of the recorder. The two toggle switches on the right foot of the pedestal control separately the drive motor in the magnetometer and the chart drive in the recorder.

The torsion gage, with specimen mount, is shown in Fig. 3, removed from its normal position on the base of the magnet. The disk shown in the hand of the operator is the specimen holder, in which the disk to be tested is held by spring action of the jaws. This holder fits on the two tapered pins visible at the top of the pedestal. Torque exerted on the specimen is transmitted through these pins to the cylindrical

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4. Special provisions to minimize parasitic thermal emf's—including automatic compensation of slidewire thermals and gold contacts in galvanometer key.
5. Exceptional convenience in reading and adjustment.
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torque shaft shown between the two rectangular uprights. This shaft is mounted between V-jewels in the top and bottom of the rectangular frame.

The rectangular box on the dial plate behind the frame is the resistance strain gage. This device contains four fine-wire resistances under mechanical strain in such a manner that a longitudinal displacement of the pin projecting through the end of the box reduces the strain in two of the resistors and increases it in the other two. The four resistors are connected in a Wheatstone bridge circuit so that displacement of the pin unbalances the bridge. With a current input to the bridge of 25 milliamperes, the output is about 20 millivolts for a displacement of about 0.0015 inch which requires a force of about 4 ounces.

The pin of the strain gage is visible in Fig. 3 at the lower end of the torque shaft, between it and the right side of the frame. A fine phosphor-bronze strip is wrapped once around the torque shaft and its ends attached to the two collars on the pin of the strain gage. The strip serves as a belt to convert the torque applied to the shaft to a force on the pin of the strain gage.

The recorder used with the instrument is of the potentiometer type. Zero of its scale is on the centerline of the chart, and the range of measurements is from plus 4 to minus 4 millivolts. By using a recorder whose range is one-fifth of the maximum output of the torsion gage, it is possible to vary the factor for converting voltage to torque by a ration of 5:1. This is accomplished by varying the current input to the bridge circuit of the gage. Then, by using a high current in the torsion gage with specimens from which a low torque is obtained, and vice versa, the recorder may be made of about equal amplitude over a 5:1 range of torque maxima.

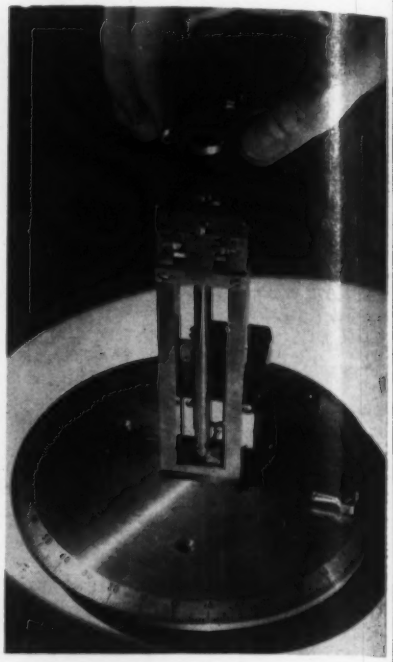
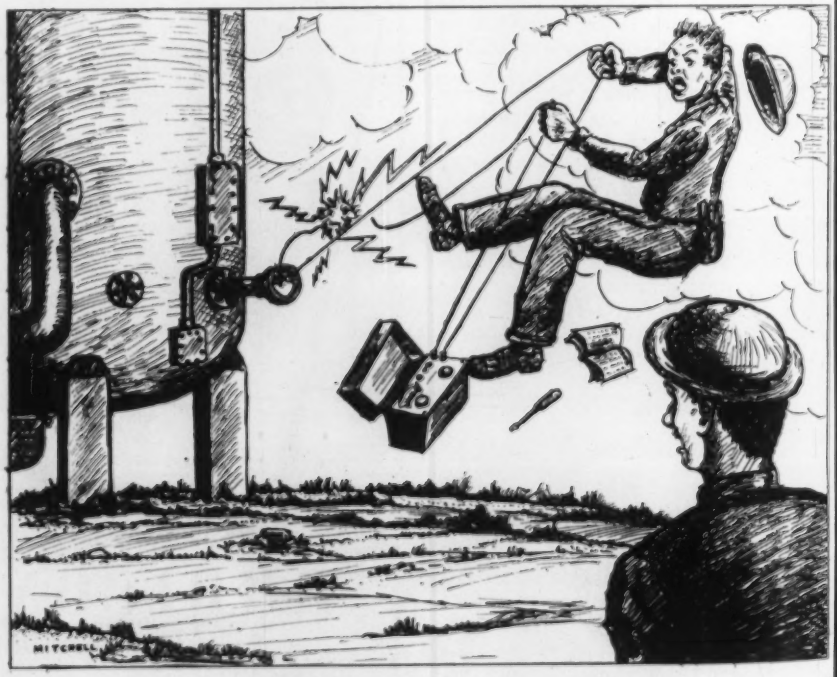


Fig. 3. Torsion gage and specimen mount. The disk in the operator's hand is the specimen holder, which fits on the two tapered pins at the top of the pedestal. The resistance strain gage which is the "heart" of the instrument is the rectangular box on the dial plate behind the frame.

Three typical curves drawn by the recorder of the instrument are shown in

*Instru*Merriment



"Did you say Iron-Constantan?"
By S. E. Mitchell, Carbide & Chemicals Corp., S. Charleston 3, W. Va.

Fig. 4. The angle scale on these plots shows the angle between the direction of magnetization and that direction in the sample which is parallel to the rolling direction. It will be noted that the maximum of curve A for the highly-directional (anisotropic) high-quality transformer steel is relatively much higher than that of the less directional type (B). The curves obtained from steels with the greatest anisotropy are always of nearly the same shape, although they vary somewhat in height. Curve C is the type obtained from testing a plain carbon steel, which magnetically is very nearly isotropic.

The torque magnetometer completes

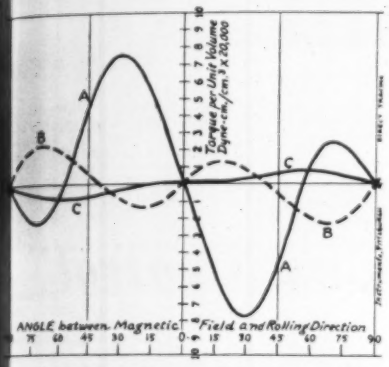


Fig. 4. Single-diagram tracing of three typical curves drawn by the recorder of the torque magnetometer. Curve A is typical of those obtained when testing high-quality transformer steel, which is very anistotropic. Curve B is for an intermediate grade of electrical steel that is slightly anisotropic. Curve C was obtained when testing a sample of plain carbon sheet steel, which is very nearly isotropic

the drawing of such curves in six minutes. This compares favorably with the 30 to 45 minutes required for the completion of such a curve by hand-plotting results obtained with earlier non-recording instruments. Also, many possibilities of error by the operator are eliminated by the autographic instrument.

The torque magnetometers which have been put into service up until now require specimens 1 inch in diameter and from 0.01 inch to 0.10 inch thick but, by suitable changes in design, specimens of other dimensions could be accommodated. The total torque on a specimen is proportional to its volume, so that for some materials, for example, tin-plate, which are thin and have a low torque per unit volume, it is particularly desirable to increase the diameter in order to increase the effective sensitivity of the instrument.

The Research Laboratory instrument has made magnetic torque testing automatic and practical in mills as well as laboratories. Covered by patent applications, improved copies of Dr. Miller's magnetometer are in operations use at Gary, Ind., sheet and tin plate mill and in the Vandergrift silicon steel mill at Irvin Works, both of Carnegie-Illinois Steel Corporation. One is also in daily use in the Research Laboratory of this subsidiary of United States Steel.

EXTRA **HERE'S NEWS** EXTRA

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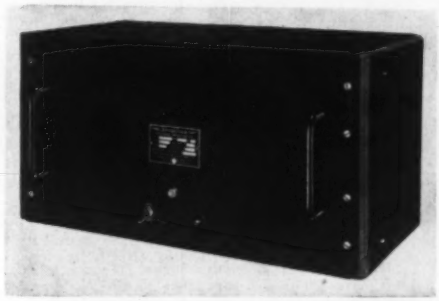

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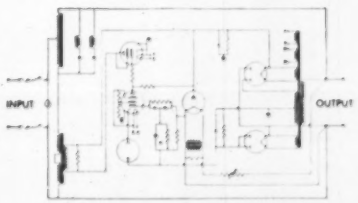

CIRCUIT DIAGRAM

Operating circuit and components of the new 500VA STABILINE.

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Vol. 4 — MAY 1949 — No. 5

Section News

AKRON

Specially invited guests for the March meeting were the instrument-minded personnel of the Columbia Chemical Division of the Pittsburgh Plate Glass Co.

The speaker was John G. Kirkpatrick, of Pittsburgh, ex-Koppers Co. Engineer, presently engaged in building a sales agency, and his subject was "The Instrument Engineer." He told of the plants of long ago, with ample storage in and between units, with low rates of flow and inherent self-regulation, and compared them with present-day units entirely opposite, requiring the best in instrumentation.

The instrument engineer should be on the process in the pilot plant stage and should be able to work right along with the plant design staff so that full advantage can be taken of the quicker response, better and more flexible control action and all of the other factors which distinguish the modern controller from the old on-off or fixed-range throttling types.

Feature of the business part of the meeting was the nomination of officers, the following being named:

President — James L. Corum, Pittsburgh Plate Glass Co.

Vice President—D. C. Milner, Kepler Engineering Co. Fred Schoonover, Goodyear Tire & Rubber Co.

Secretary—Fred Appel, Jr., Pittsburgh Plate Glass Co. Emory W. Clark, B. F. Goodrich Co.

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Section Delegate—C. B. Luther, B. F. Goodrich Co.

—Fred Appel, Jr., Sec'y

BOSTON

The sixth meeting of the season was held at the Hotel Statler on March 30, 1949. Preceding the meeting at 2:30 P.M. there was a tour of the Nathaniel Tufts Meter Works, American Meter Co., 455 Commercial Street, Boston.

The meeting at the Hotel Statler was sponsored by the American Meter Co. The arrangements were made by Mr. A. M. Wolfe, New England Manager of the American Meter Co. and his assistants, R. F. Connors, and H. F. Cain.

The after-dinner speaker was Mr. Louis Hickman of Dallas, Texas, his subject was "Flow and Pressure Transmission."

The next meeting will be held at the Esso Refinery, Everett, Mass., on April 27, 1949. Mr. F. G. Tatnall of the Baldwin Locomotive Works, will have as his topic, "Industrial Application of Strain Gages." At this meeting there will also be the election of officers.

—J. H. Condon, Corr.

CALIFORNIA

The joint Meeting of the California and China Lake Sections on April 8th at the U. S. Naval Ordnance Test Station at Inyokern, China Lake was an outstanding event. A record group of 260 members, ladies and guests of the California Section journeyed the 150 miles from the Los Angeles area to the desert base via auto and bus to visit the range and laboratory facilities in a tour which represented splendid planning and gracious hospitality by the China Lake Section.

Directly following the registration at 10:00 A.M. the group toured Station Ranges in Navy buses and on Range K observed track launching of a five-inch rocket accelerated by 2 three-inch booster rockets.

Luncheon in the Cafeteria was followed by conducted tours of facilities, instrumentation and exhibits of the huge Michelson Laboratory and a bus tour of the China Lake Community.

Meeting from 4:00 to 6:00 P.M. at the Commissioned Officers' Club included a discussion of the Tektronix 512 Oscilloscope and Rutishauser Pressure Measuring Equipment by Mr. R. L. Morgan of Neely Enterprises, Inc. The 48 ladies comprising the visiting group were meanwhile enjoying the special program prepared for them, including tours of Michelson Laboratory and Bennington Plaza, Luncheon in the Club Sun Room, tour of the China Lake Community and a Bridge-Tea at the Club.

6:00 P.M. Dinner at the Commissioned Officers' Club was highlighted by Mr. H. A. Van Dyke, who introduced officers of the California and China Lake Sections and welcomed members, ladies and guests of the visiting group. Rear Admiral W. G. Switzer then presented a Naval Citation to Dr. I. H. Swift of the Aviation Ordnance and Test Department for Technical contributions to the war effort. Dr. Brode, Assistant Director of the Bureau of Standards in Washington, climaxed the program with an outline of current scientific programs of national and international significance. The next meeting is tentatively scheduled for May 3rd at Roger Young Auditorium in Los Angeles. Mr. Nolte of the Barton Instrument Co. of Los Angeles will present a discussion on Bellows Actuated Instruments.

—Chris Wagner, Corr.

CENTRAL INDIANA

The April 5th meeting was held at the Rock Island Refinery, Indianapolis. A tour of the plant was preceded by a talk by Mr. Leon Stewart, explaining in outline the methods of cracking and control systems. Mr. Stewart was assisted in conducting the tour by Mr. Jones, plant superintendent, and members of his force.

The May 4th meeting will be held at the Gothe Link Observatory. It will be at 7:30 P.M. central daylight saving time. The speaker will be Dr. Frank K. Edmondson of Indiana University. The Link Observatory is located two miles past Brooklyn, Indiana, on State Road 67.

—E. E. Taylor, Corr.

CHARLESTON

On March 7th, the Section held its regular meeting in the Assembly Room of the Kanawha Hotel. The guest speaker was Mr. Alexander Thackera of the Mason-Neilan Co., Marshalltown, Iowa, who gave an excellent talk on "Liquid Level Controls." He stressed the displacement type of instrument showing slides of interesting applications. During his talk, Mr. Thackera discussed, at some length, the "Whys and Wherefores" of the design of these instruments.

The April meeting of the Charleston Section was held in the same place on April 4th. The speaker was Mr. Don Burns of the Hays Corp., Michigan City, Indiana, who spoke on the subject "Combustion Controls." He pointed out the merits of the electric versus the pneumatic control systems and discussed novel means of applying reset and derivative control. Mr. Burns also illustrated his talk with slides showing the application of cascaded controls to boiler installations using different types of fuel, stokers, and mills.

Both of the above meetings were preceded by a dinner at the Army and Navy Club.

—C. G. Fellows, Vice-Pres.

KANSAS CITY

The Kansas City Section had its regular meeting on Tuesday, March 29th, at the Blue Bird Cafeteria, 3215 Troost Avenue. Forty-five members and guests attended.

Our guest speaker was J. T. McFarland, District Manager of the St. Louis Office, Hagan Corp., who presented an illustrated talk on "Hagan Ring-Balance Instruments." Mr. McFarland explained how the instrument was built, automatic pressure and temperature compensation and application to industrial processes.

Mr. McFarland extended the best wishes from the St. Louis Chapter ISA. He explained to the members the progress to date of making arrangements for speakers who could plan their itinerary to talk to various ISA Societies on one trip. Members were requested to list the types of subjects they wish to have the speakers cover. Our program committee will tabulate this information in setting up the program for next year.

—W. A. Reichow, Corr.

MONTREAL

The Montreal Section held a regular monthly meeting on the 28th of February in the Canadian Legion Memorial Building, Montreal. Mr. Lyle Eige of the Fischer Governor Co., Marshalltown, Iowa was speaker. His talk covered control valve design and

(Continued on page 448)

See Article on Next Page

The Author

Robert T. Sheen

Mr. Sheen received his B.S. Ch.E. from Lehigh University in 1931, Ch.E. in 1936. He was a chemical engineer with Monsanto Chemical Co., 1931-32 and engaged in consulting work 1932-43. In 1937, with M. Roy Sheen he founded the Milton Roy Co. of which he is president.

INSTRUMENTATION
By and With Controlled Volume Pumps

By ROBERT T. SHEEN*

A CONTROLLED volume pump is an instrument—an instrument to accurately meter liquids in measured volumes against a positive pressure differential between suction and discharge of pump. This metering action is possible with a degree of accuracy exceeding that of many flow meters—in most instances to a fraction of 1%. The pump consists of a plunger reciprocating in a properly designed displacement chamber at a speed sufficiently slow to assure on each stroke complete positive displacement of a volume of liquid equivalent to a cylinder of plunger diameter and stroke length. A typical design of a controlled volume pump is shown in Fig. 1. A double check valve is employed on both the suction and discharge of the displacement chamber. In the event one ball is held off the seat by any particle in suspension in the liquid being pumped, the chances are that the second ball will hold assuring positive check valve action. The liquid end is further designed to automatically discharge any air or gas that may enter with the liquid in a single stroke of the plunger. Any pockets in the displacement chamber in which air could be trapped would impair the volumetric efficiency of displacement of the pump by permitting alternate compression and expansion of the gas bubble with reciprocation of the plunger.

The capacity of a controlled volume pump is a function of three variables; area of the plunger, stroke length, and the speed. Adjustment of the stroke is the common method normally employed on a constant speed pump for adjustment of capacity. Fig. 1 illustrates stroke adjustment by screw method to obtain variation in the capacity by altering the position of the trunion in the slot of the drivewheel while the pump is not operating. Microadjustment of the stroke is the second method and illustrates adjustment of pump capacity while the pump is in operation. (Fig. 2) By operating a hand wheel driving a chain to the rocker box, a lead screw is rotated. On this lead screw is mounted a connecting rod to the crosshead of the pump. There is a fixed throw from the low speed shaft of the motor gear driver to this rocker box and a variable throw from the lead screw positioning the connecting rod to the crosshead of the pump. A vernier dial on the top of this rocker box indicates the stroke length to within 1/750 of full stroke. A change in capacity down to 0.13% may be indicated by means of this adjustment.

Automatic Chemical Feed Systems

Controlled volume pumps will normally function efficiently at speeds as low as 1 stroke per minute to as high on certain applications as 100 strokes per minute. With plunger diameter and stroke length of a given pump held constant, variation of speed within a selected portion of this range will affect the variation of the capacity delivered by the pump directly proportional to speed. Accurate speed control can be obtained by means of electronic control such as the General Electric "Thymotrol." This application has been further described in considerable detail by the author in a previous paper (1). Speed control over a range as high as 100 to 1 is possible by means of this system although the usual practical range is 10 or 20 to 1. At any given speed setting, speed is automatically held constant irrespective of change in load. This is a characteristic definitely necessary for application of this control to automatic chemical feed systems. The speed will not vary more than plus or minus 1% with a-c. voltage variation of plus or minus 5%. Calibration for motor speed versus potentiometer setting is practically a straight line and this can be reset with an accuracy of better than 2%. This electronic control is available for motors from small fractional horsepower sizes up to practically any large integral horsepower.

The largest application of Thymotrol with controlled volume pumps is on proportioning systems. Fig. 3 will illustrate details of such a system. A conventional type of flow meter is used for measuring main line flow and positioning a 10,000 ohm potentiometer. The flow meter sets the potentiometer in direct relation to rate of flow and controls the speed of the motor on the pump automatically controlling the quantity of chemicals delivered by the pump. Since motor speed is directly proportional to rate of flow, chemical feed is likewise directly proportional to flow. The chemical pump is operating continuously, instantly changing feed rate with any change in flow rate. This system has a number of advantages over the older type of systems designed to feed in slugs and to work from contacts on a flow meter.

Applications of this flow control for proportioning have been made for water treatment (2). sewage treatment, and treatment of petroleum products. Installations have been made for odorization of natural gas by metering the gas flow and adding the odorant proportional to gas flow by means of the pump. Another interesting application is in chemical processing; for example, one such process is in operation proportioning the flow of molten naphthalene to hot air in the manufacture of phthalic anhydride.

*Presented at the third annual conference of the Instrument Society of America, Sept. 13-17, Philadelphia, Pa.

NOTE: Statements and opinions advanced in papers are to be understood as individual expressions of the author and not those of the Society.

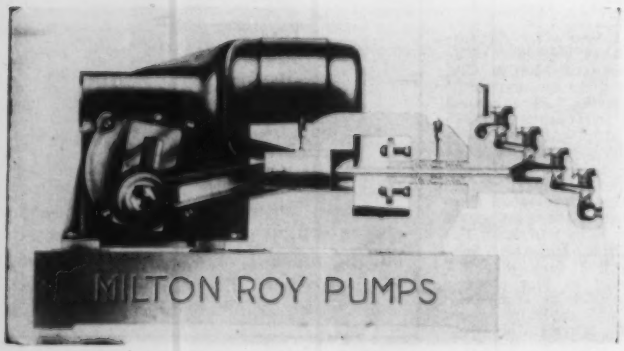


Fig. 1. (Left) Typical design of a controlled volume chemical pump.

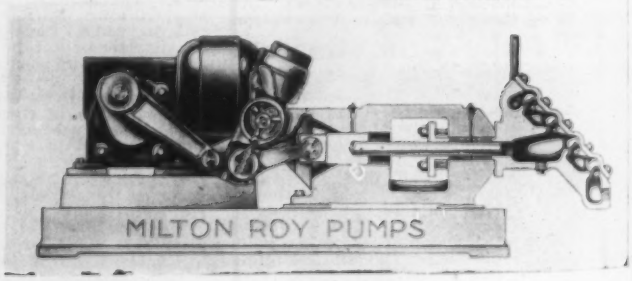


Fig. 2. Micro indicating stroke adjustment with cover plate liquid end design.

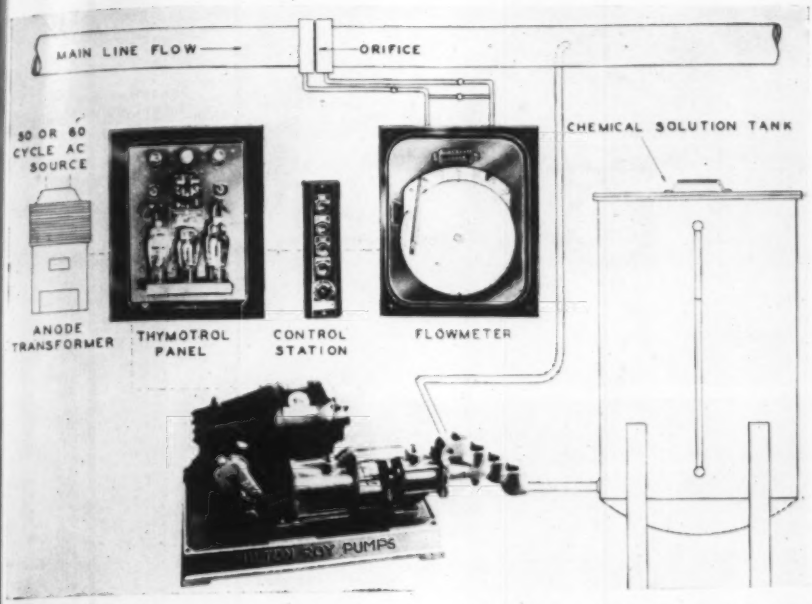


Fig. 3. Automatic proportioning on ratio control system. Pump motor speed and rate of chemical addition by pump is constantly and directly proportional to metered main line flow.

This speed control can be used in conjunction with pH meters and controllers for a pH control system. The preferred approach for pH control is through the use of motorized stroke adjustment. This is because the motorized stroke adjustment is capable of reducing the length of the stroke entirely to zero so that if necessary and called for by the controller, the pump motor may be operating but there will be no chemical delivered by the pump. The hand wheel on this micro adjustment can be replaced by a small reversible motor with the other end of the high speed shaft of this reversible motor driving through a gear reduction train to set a slidewire. This slidewire may be balanced with a slidewire in a controller on two legs of a Wheatstone Bridge circuit. Automatic control of the length of the stroke is thus possible. This finds application in automatic pH control systems regulating the length of the stroke automatically from a pH controller and thereby the quantity of chemical, acid or alkali, fed to a process as called for by pH value Fig. 4. In pH control systems, it is necessary to allow for lag and rate of reaction. The systems must be designed properly to avoid hunting (3). If a pH controller must follow a large change in rate of flow, considerable hunting will also result. It is possible to compensate for variable flow on a pH control system by using the two control variables on a single pump Fig. 5. This is done by varying the speed of the pump through a Thymotrol to regulate the speed of the pump drive directly proportional to rate of flow and use the second variable, pH value, to set automatically the length of the stroke of the plunger on the pump. With such a unit, pH may be controlled without hunting and with a higher degree of uniformity than possible with a single pH control alone.

Any type of metered variable can be used for regulation of the quantity of chemical delivered by the pump either through control of motor speed or control on the length of the stroke. Two flows can be ratioed by a single motor gear drive by mounting two pump cylinders on each side of a low speed drive shaft. Special units can be assembled for ratio control of a number of streams driving through a common high speed shaft to a number of gear reducers. Such an application was successfully engineered and applied to food processing, regulating the speed of the entire pump automatically from a liquid level through Thymotrol Fig. 6. The food product was received from an open end process at the rate of 20 to 35 gallons per minute. It was desired to add three treating chemicals to this food product at a rate exactly proportional to the rate at which the material was received and then to pump the material together with the three treating chemicals under pressure to a reaction vessel. The problem was solved by receiving the food product in the small surge tank and installing liquid level control on the surge tank. The first two chambers of the controlled volume pump pumped from the surge tank handling the liquid from the process. The speed of the drive on this unit was regulated through Thymotrol from the liquid level so that, if the tank level started to rise, the entire pump unit speeded up or if the level started to fall, the pump unit slowed down. From the same high speed shaft, drives were taken through speed reducers to the three chemical pumps so that the three pumps speeded up or slowed down in exact proportion to the speed of the main pump handling the liquid from process, Fig. 7. Proportionality of feed was thus assured and it is possible to change the ratio of any of the three treating chemicals while the entire system is in operation.

Similar arrangements of gang drive units make possible accurate blending of a number of streams, controlling the exact ratio of one stream to the other by simply setting the stroke length on the various cylinders of the gang drive pump. Applications for this gang drive principle have been found in chemical processing, in food formulation, and in pharmaceutical manufacture.

Automatic Titration Systems

In a number of processes, it is desirable to control the strength of a solution in a range where there is relatively little change in a metered variable. Up to the present time, there has been no system of control available that would accurately maintain such solution strength. Reference is particularly made to strengths of caustic or acid baths within such limits of concentration as would not be detected by pH value, or where relatively little change is shown in conductivity or specific gravity.

The strengths of such solutions are commonly determined by titration

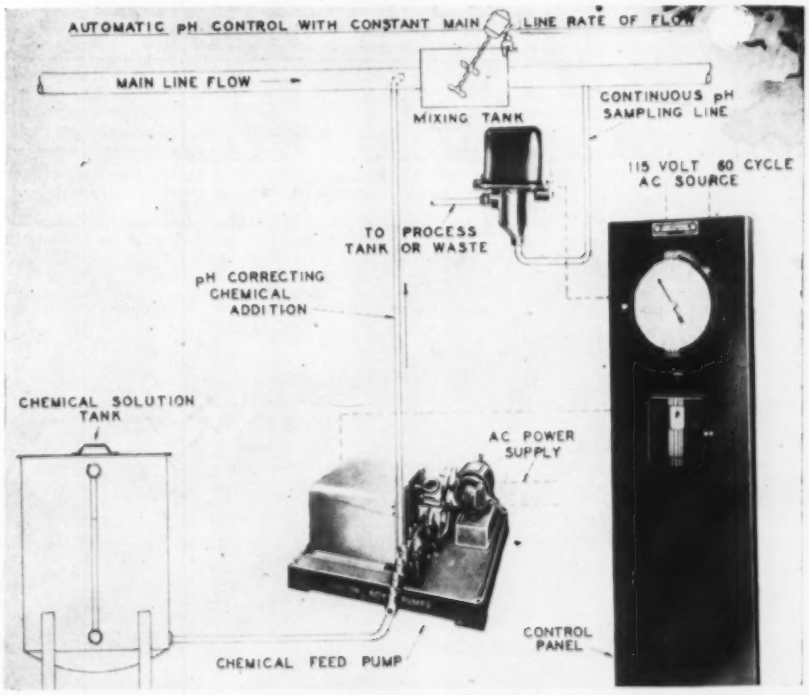

AUTOMATIC pH CONTROL WITH CONSTANT MAIN LINE RATE OF FLOW
MAIN LINE FLOW
MIXING TANK
CONTINUOUS pH SAMPLING LINE
115 VOLT 60 CYCLE AC SOURCE
TO PROCESS TANK OR WASTE
pH CORRECTING CHEMICAL ADDITION
CHEMICAL SOLUTION TANK
AC POWER SUPPLY
CONTROL PANEL
CHEMICAL FEED PUMP

Fig. 4. Automatic pH control with constant main line rate of flow. pH Meter adjusting length of stroke of chemical pump to deliver chemical continuously as required by the pH controller.

wherein a sample of the solution is reacted with a known volume of standard solution whose strength is known. The quantity of this standard solution required to react with the unknown is a definite measure of the strength of the unknown solution. Such periodic determinations are tedious and up to the present time, have not been incorporated in automatic control systems. To answer these problems, an automatic titration system has been designed to use a duplex controlled volume pump to continuously titrate a sample from the liquid bath with a standard solution. The sample is measured by one side of the duplex pump while the other side meters to the sample in direct ratio and in exact proportion a measured quantity of standard titrating solution Fig. 8. One quart to two gallons per hour will normally be required for a sample. The first preliminary announcement of this method was made in a recent paper by the author (4) and it is the purpose of this paper to give further details and applications. Fig. 9 is a detail of the titration cell showing the intake connection from the titration pump to both sides of this cell.

On a number of strong solutions, dilution water will be required. Where it is

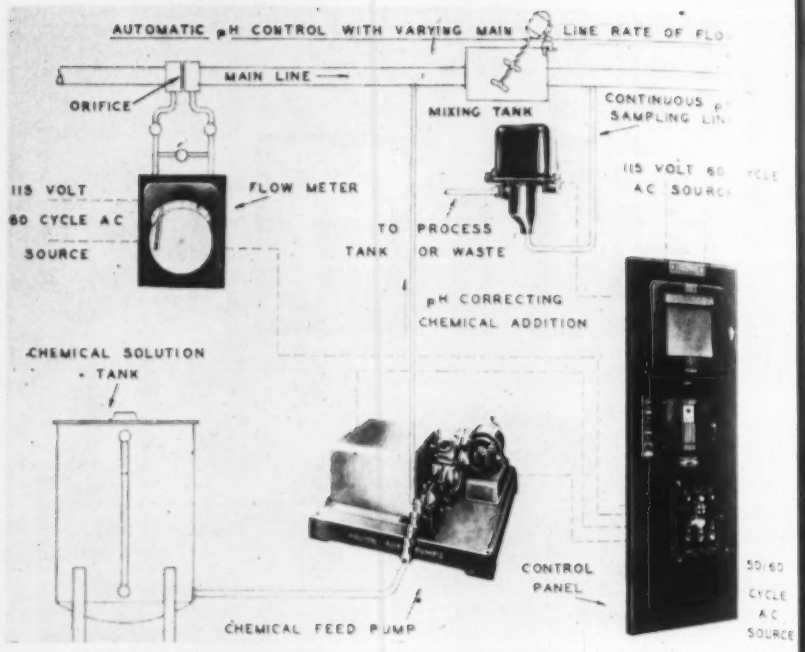


Fig. 5. Automatic pH control with varying main line rate of flow. Capacity of pump independently adjusted for two variables with motor speed proportional to main line flow and length of stroke set by pH meter and controller.

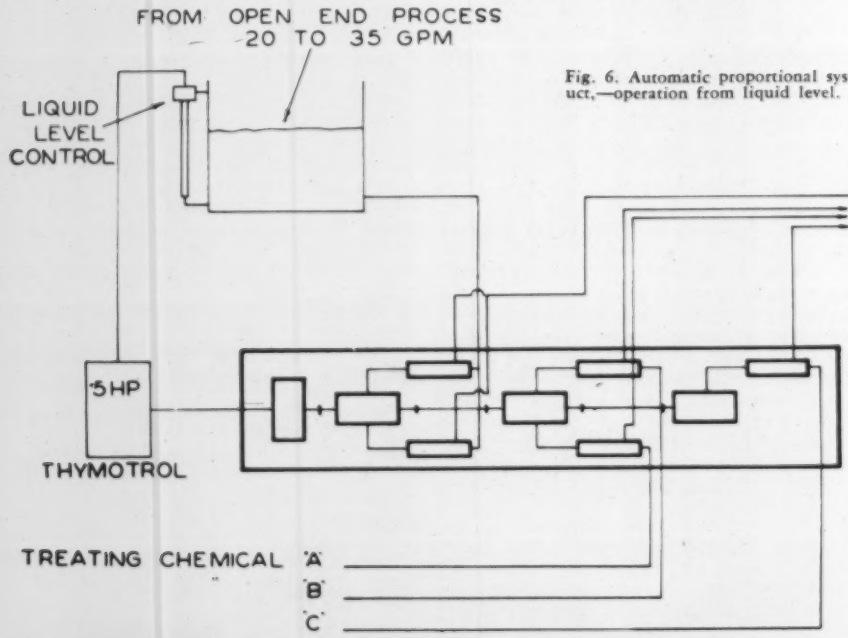


Fig. 6. Automatic proportional system for treatment of food product,—operation from liquid level.

necessary, this can be introduced to the cell regulating the flow by supplying water at a constant pressure to a variable orifice valve and setting the desired flow at a rate as indicated by a rotameter or similar flow indicating device. The contents of the cell are continuously circulated by means of a small pump at a ratio of 10 to 100 times the rate of flow to the cell. This pump is connected externally to and immediately adjacent to the cell. This was found preferable to attempting any direct agitation. The pH value can then be measured directly from a glass electrode

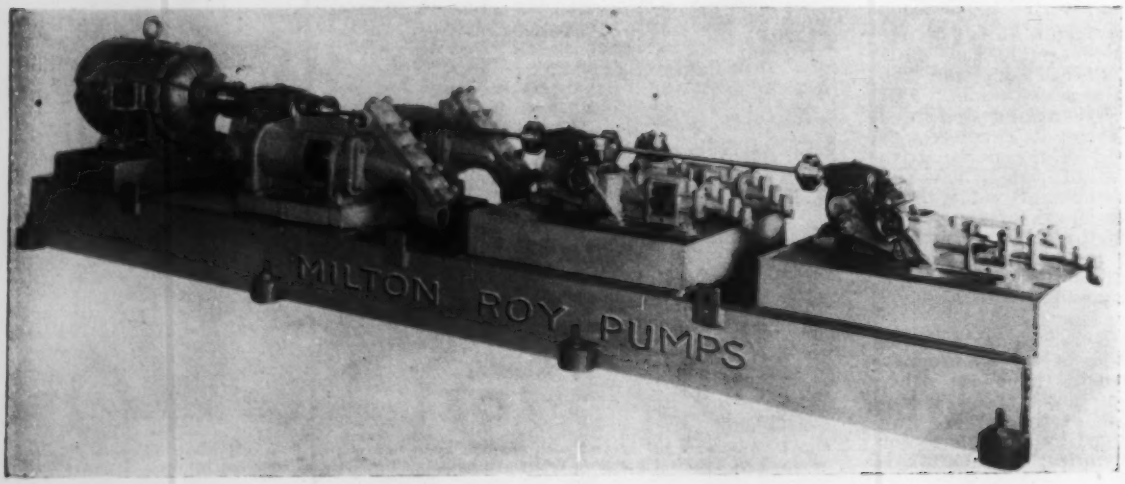


Fig. 7. Gang pump design for multiple stream ratio control.

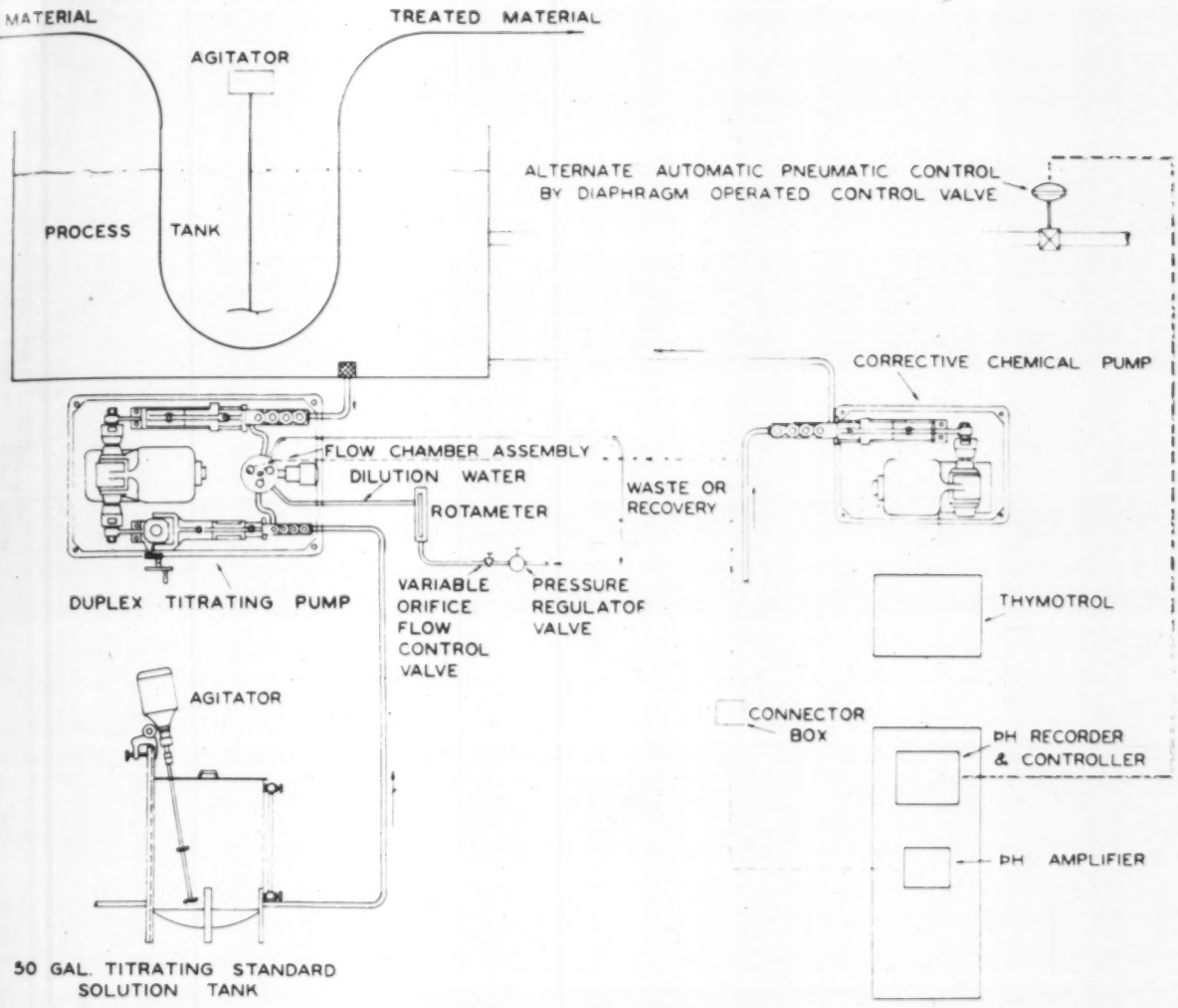


Fig. 8. Titronic system concentration control.

stem inserted in the top of this cell. idation potential could likewise be easured. Where the result of a titra- n can be metered, the metered vari- le can be employed for control in this pe of system. The basic system incor- rates these fundamentals of continu- s titration to a desired endpoint util- ng the continuous measurement of is endpoint for control of a process. In the application of the concentra- n control system, the length of the roke on the microadjustment for the andard solution can be set in accord- ce with any slight variation in nor- ality of the standard solution to give desired control point. In other words, e strength of the standard solution n be approximately prepared by mix- g a certain weight of acid or alkali ith a certain quantity of distilled ater in the tank. A check titration will en give the exact value of the stand- d solution. The length of the stroke the standard solution side of the mp may then be set by means of the icroadjustment to correspond to this act solution strength and thereby, set e control point desired for control of e concentration accordingly.

Fig. 10 may be used for an illustra- on of an exact application of this sys- m. The problem in this case was the ntrol of a caustic soda bath at 0.2 rmal controlling the bath within plus minus 0.02 normal. A product was ing treated in the caustic soda and on leaving the bath would take with it some of the liquid and also cause some carbonation of the caustic soda in the bath. Obviously, control by conductivity, specific gravity, or pH value direct would not give the desired control. Titration of the bath with sulfuric acid is not satisfactory for control as shown by the first set of curves in Fig. 10. Starting with the fresh caustic, Curve No. 1, a steep breakpoint curve is shown due to the negligible buffer action present. After the process has been in operation for a period of time, however, and after some carbonation has taken place, the titration curve is as in II, and the difference between these two curves is too great for accurate control. By using a buffer acid such as phosphoric acid, a family of curves is obtained that will give the control required. The buffer action of the phosphoric acid then takes control in the system. The control point is taken at pH 8.5, the break point between tri-sodium and di-sodium phosphate. The range of plus or minus 0.02 normal corresponds to range B. By projecting from the abscissa to the curve

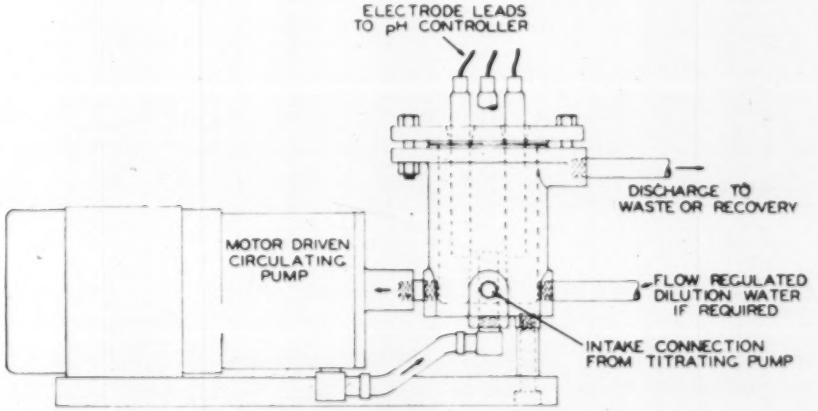

ELECTRODE LEADS TO pH CONTROLLER
DISCHARGE TO WASTE OR RECOVERY
MOTOR DRIVEN CIRCULATING PUMP
FLOW REGULATED DILUTION WATER IF REQUIRED
INTAKE CONNECTION FROM TITRATING PUMP

Fig. 9. Titronic flow chamber assembly.

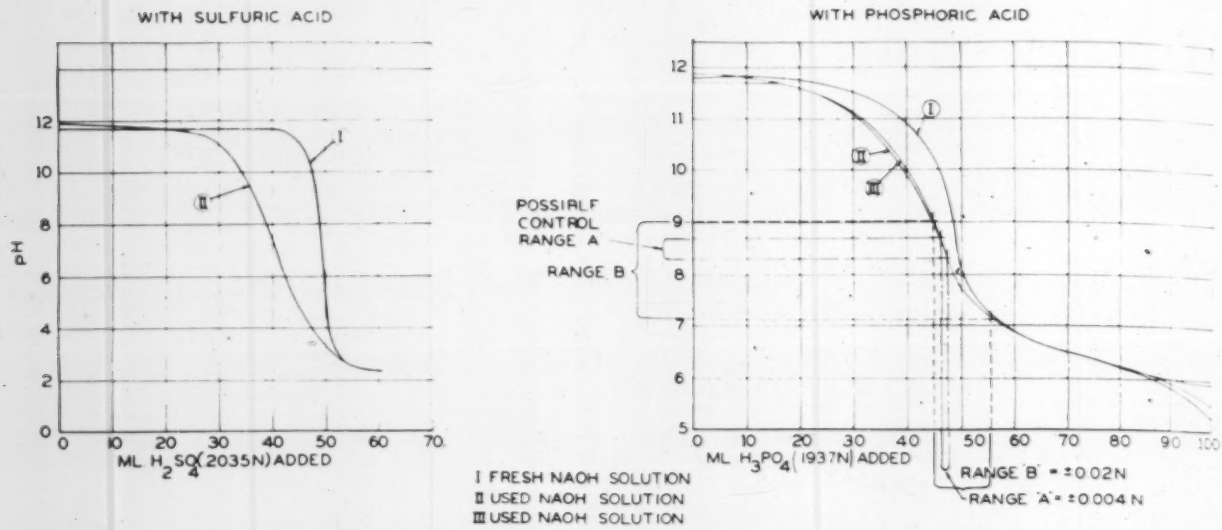


Fig. 10. Application of titronic system to caustic concentration control.

and referring to the ordinate, it is noted that a pH control between pH 7.1 and 9.0 will satisfy the requirements. Obviously, it is possible to obtain a control much closer than this as it is possible to accurately control within plus or minus 0.2 pH. By taking this range, control range A pH 8.3 to 8.7 and referring back to the curves from the ordinate and dropping to the abscissa, it will be found that this is equivalent to controlling the strength of caustic soda at plus or minus 0.004 normal.

Another example of continuous regulation of caustic concentration is the control of the strength of digestor liquor in the manufacture of paper pulp. Titration curves of strong caustic soda with both hydrochloric acid and phosphoric acid on the same samples are shown in Fig. 11. In this case, the unbuffered hydrochloric acid would prove perfectly satisfactory for control as far as curve characteristics are concerned. This is due to the various buffer materials present in the caustic green liquor. These buffer materials consist of the products extracted from the wood by the digestion including various hemi-celluloses, tannins, lignins, etc. The two acids are equivalent in strength at the point of complete neutralization at approximately pH 3.0. At the point of conversion from tri to di-sodium phosphate, 8.5, it is interesting to note that just half the quantity of phosphoric acid is required compared to the quantity of hydrochloric acid due to the formation of the intermediate salt. For a commercial application, it would be preferred to handle dilute sulphuric acid or the phosphoric acid as the titrating medium rather than the hydrochloric acid due to difficulty with materials of construction and the preparation of hydrochloric acid in sufficient quantity in corrosion resistant vessels.

It is, of course, possible to use this same type of system working in reverse for control of the strength of acid in acid baths. One typical process was investigated in which sulphuric acid was present in a range from approximately 8 to 13% along with various other organic and inorganic ingredients. Titration curves of three different strength baths are shown in Fig. 12. The first group of curves shows the results of

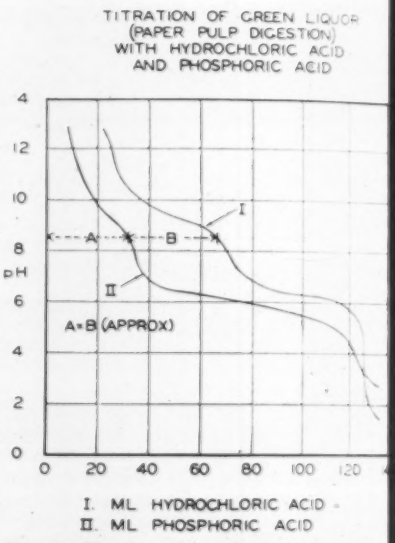
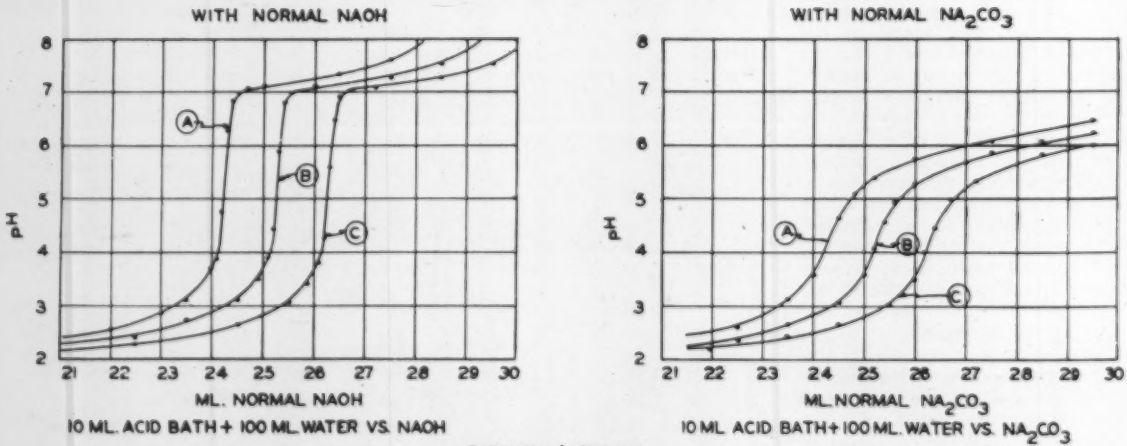

TITRATION OF GREEN LIQUOR (PAPER PULP DIGESTION) WITH HYDROCHLORIC ACID AND PHOSPHORIC ACID
pH
A=B (APPROX)
I. ML HYDROCHLORIC ACID
II. ML PHOSPHORIC ACID

Fig. 11. Titration of caustic green liquor (pul digestion).


WITH NORMAL NAOH
WITH NORMAL NA_2CO_3
pH
ML. NORMAL NAOH
ML. NORMAL NA_2CO_3
10 ML. ACID BATH + 100 ML. WATER VS. NAOH
10 ML. ACID BATH + 100 ML. WATER VS. NA_2CO_3

BATH NO.	% H_2SO_4
A	9.50
B	9.87
C	10.27

Fig. 12. Acid process bath titration curves.

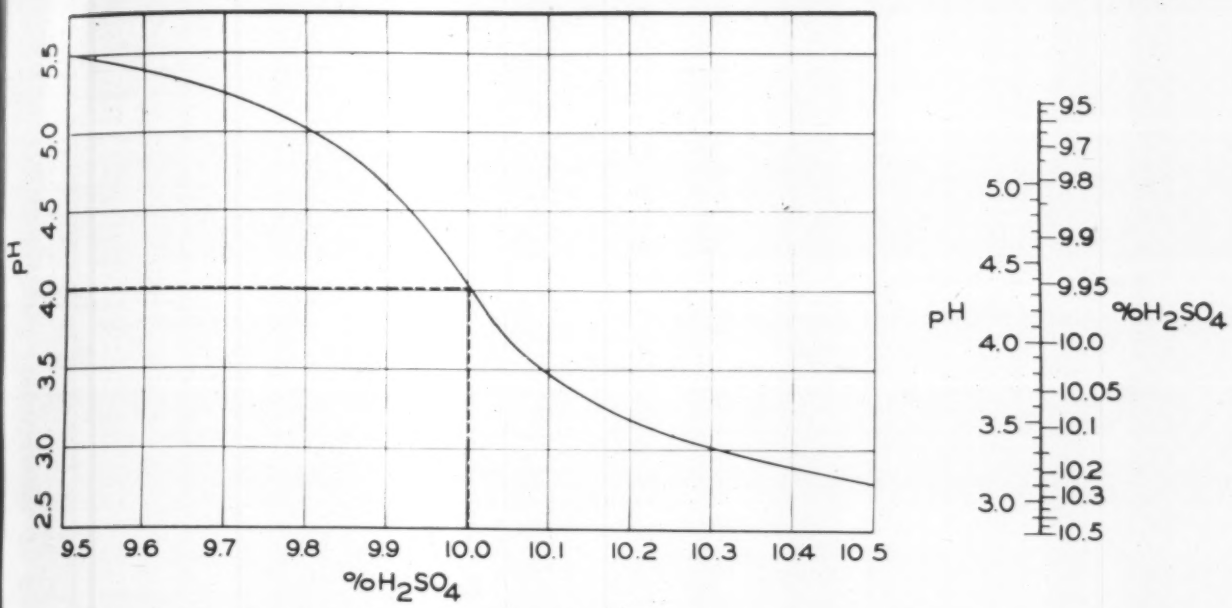


Fig. 13. Relationship of pH from titration and concentration of H_4SO_2 in acid bath.

tration with normal caustic soda, sharp buffer action being shown immediately above pH 7. The steep portion of the curve between pH 4 to 7 is too steep to permit accurate control. Some buffer action is desired for application of this concentration control principle. Titration of the same baths with normal sodium carbonate gave the second family of curves and it is evident that control at pH 4.5 would give excellent results for accurate concentration control of sulphuric acid.

It is possible to determine the strength of the acid with continuous titration without using the control feature of the system. There are two ways that this can be done. From data that were secured, a curve could be plotted over a limited range of sulphuric acid concentration, taking a portion of the curve (Fig. 12) on which satisfactory buffer relationship existed; for example, pH 2.5 to 5.5. The results are shown in Fig. 13, together with a scale indicating the correlation between the pH and percent sulphuric acid on this portion of the curve. In this case, only the titrating pump and pH recorder is necessary. If, on the other hand, it is desired to titrate to a definite pH value and continuously record the results of the titration over a larger range, then the system as shown in Fig. 14 can be employed. In this system, the pH recorder controller is used to automatically control the length of the stroke on the standard solution side of the titrating pump. A second recording meter continuously records the length of the stroke which is a direct measure of the quantity of standard solution required for the titration and is therefore a continuous record of the titration value of the process. If it is desired to ultimately control the strength of the process, this may be done by disconnecting the motorized microadjustment feature on the titrating pump, changing this back to hand adjustment.

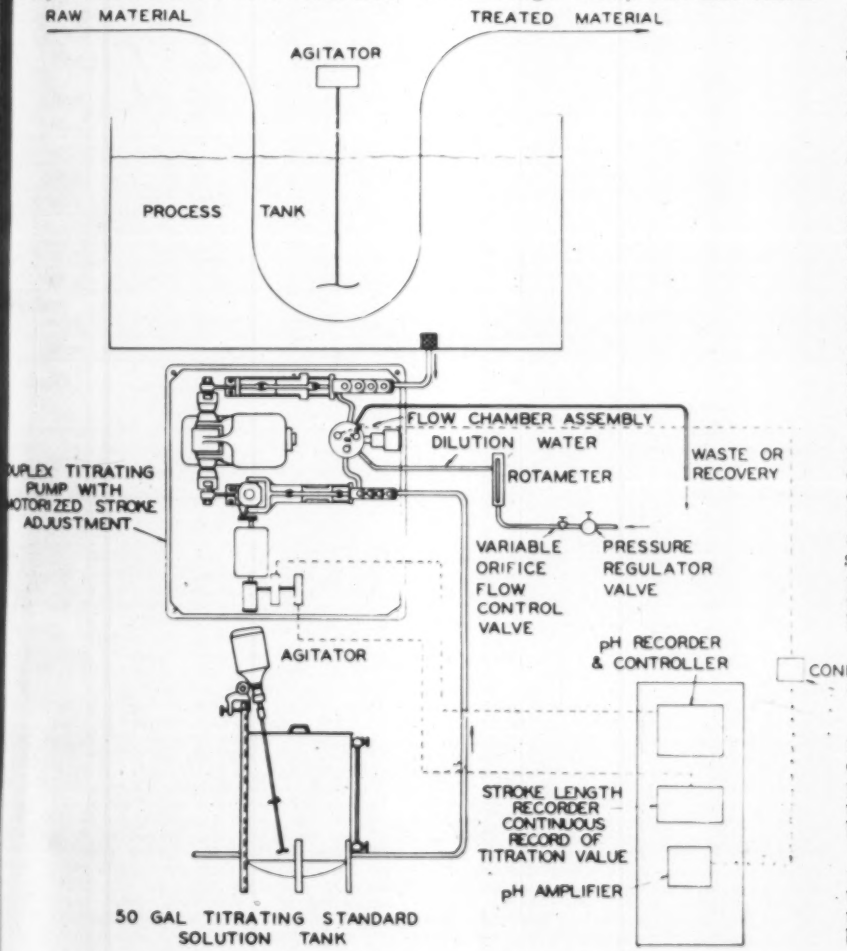


Fig. 14. Continuous titronic recording system.

These titration systems can be used for control of hydrogen peroxide or chlorine bleach baths by measurement of oxidation potential instead of measurement of pH value. In such an instance, titration with a reducing agent such as sodium nitrate or sodium thiosulphate would be used. This would bring the oxidation potential curve to the breakpoint and to a rate of slope where measurement of relatively large changes of oxidation potential are possible, thus permitting the results of continuous titration to control concentration of bleach baths.,

The application of these principles will permit automatic control of concentrations on many solutions and in systems where such control has heretofore been thought impossible.

SECTION SECRETARIES AND MEETING DATA

	Telephone	*Date*	*Dinner*	*M*
Akron: Fred Appel, 932 Columbia Ct., Barberton, Ohio.		4 Tues.	X	
Aruba: A. S. MacNutt, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.		1 Tues.	X	
Atlanta: H. Kockritz, Fischer & Porter Co., 84 Peachtree St., Atlanta, Ga.		4 Mon.	X	
Baltimore: Felix Cox, Bethlehem Steel Co., Sparrows Point, Md.		2 Fri.		
Boston: C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass.		Last Wed.	6:00	
California: D. D. Taylor, 234 E. Colorado, Pasadena 1, Calif.		1 Tues.	6:30	
Central Illinois: T. A. Carroll, 721 Hurlburt St., Peoria, Ill.		1 Wed.	6:30	
Central Indiana: H. F. Coffey, 110 G Nelson Ave. Tyndall Towne, Indianapolis, Ind.		1 Tues.	X	
Charleston: Albert H. Hix, 1529 B Dixie St., Charleston 1. W. Va.		1 Mon.	X	8:00
Chicago: Floyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago, Ill.		1 Mon.	6:30	8:00
Cincinnati: Smith Hickenlooper, 1147 Beverly Hills Dr., Cincinnati, Ohio.		3 Fri.	X	8:00
Cleveland: L. H. Waldrip, 3030 Euclid Ave., Cleveland, Ohio.		4 Wed.	6:30	8:00
Cumberland: Clyde Babst, P. O. Box 447, Cumberland, Md.		*Tues. after 4 Mon.*	6:30	8:00
Detroit: T. S. Cawthorne, 570 Maccabees Bldg., Detroit 2, Mich.		3 Tues.		
Eastern New York: Wm. J. Claffie, Winthrop-Stearns, Inc., 33 Riverside Ave., Rensselaer, N. Y.		1 Tues.	6:30	8:00
Gulf Coast: A. E. Bunn, 2237 North Street, Beaumont, Texas.		3 Tues.		
Houston: E. E. Kleir, 2518 S. Blvd., Houston 6, Texas.		Last Mon.	X	8:00
Inyokern, China Lake, Calif.; A. G. DeBell, U.S. Naval Ordnance, Test Sta., China Lake, Calif.				
Kansas City: Lewell F. Spies, J. F. Pritchard & Co., 908 Grand Ave., Kansas City, Mo.		Last Tues.	6:30	7:30
Louisville: H. C. Scherffius, 980 Palarka Rd., Louisville, Ky.		4 Tues.	X	8:00
Montreal: F. S. McCarthy, Canadian Industries, Ltd., Box 10, Montreal, Quebec, Canada.		Last Mon.	X	8:00
New Jersey: W. D. Archibald, 605 Westminster Ave., Elizabeth 3, N. J.		1 Tues.	6:00	
New Orleans: W. H. Haney, 2927 Music Avenue, New Orleans, La.		*No Regular Date*		8:00
New York: Norman J. Cherry, Merrick, L. I., N. Y.		Last Mon.	6:30	8:00
Niagara Frontier: K. J. Fees, RFD #1, Niagara Rd., Niagara Falls, N. Y.		4 Mon.	X	8:00
North Texas: F. Zapffe, Lone Star Gas Co., 2701 Logan St., Dallas 1, Texas				
Northern Indiana: C. P. Haynes, 935 177th Place, Hammond, Indiana.		3 Wed.	6:30	7:30
Oak Ridge: John H. Clark, 138 Clayton Hall, Oakridge, Tenn.		1 Wed.	6:30	7:30
Ontario: John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada.		3 Thur.	6:45	
Philadelphia: C. W. Wood, 6908 Market St., Upper Darby, Pa.		3 Wed.	X	8:00
Pittsburgh: L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pittsburgh 13, Pa.		4 Mon.	6:30	8:00
Presque Isle: R. P. Marshall, 161 W. Main St., North East, Penna.		4 Tues.	X	8:00
Richland: R. S. Hammond, 402 Abbott, Richland, Washington.		2 Wed.	X	7:30
Rochester: R. C. Swartz, Jr., 1201 Granite Bldg., Rochester 4, New York.		4 Tues.	X	8:00
St. Louis: W. G. Lee, 4710 Delor St., St. Louis 16, Mo.		1 Wed.	X	8:00
Sarnia: C. G. Elder, 323 Maria St., Sarnia, Ont., Canada.		2 Fri.	X	
South Bend: Charles E. Williams, 921 Lawndale Avenue, South Bend, Ind.		1 Thur.	6:30	7:30
South Michigan: Homer Kuiper, 2517 Hillsdale, Kalamazoo, Mich.		2 Wed.	6:30	8:00
South Texas: H. C. Givens, La Gloria Corp., P. O. 637 Falfurrias, Texas.		1 Tues.	X	7:30
Tennessee: L. W. Thayer, 1837 Oakwood Dr., Kingsport, Tenn.		*No Definite Night*	7:00	8:00
Tulsa: C. R. Horton, 8211 E. 7th, Tulsa, Oklahoma.		1 Mon.	X	7:30
Twin Cities: Ray Hooper, International Div. Minneapolis-Honeywell Reg. Co., 2753 Fourth Ave., Minneapolis 8, Minn.		4 Tues.	6:30	
Washington: Edwin G. Brown, c/o American Instrument Co., 8010-20 Georgia Avenue, Silver Spring, Md.		3 Mon.	X	7:30
Wayne County: R. L. Swenson, 1569 13th St., Wyandotte, Michigan.		3 Mon.	6:30	8:00

(Continued from page 441)

characteristics, and the considerations in the selection and application of diaphragm motor valves. A new feature of the meeting was the recording of Mr. Eige's excellent discussion so that the talk could be provided to remote mills whose ISA members and potential members could not conveniently attend the session.

At the March 28th meeting a very interesting and informative talk, "Air Function in Automatic Control Mechanism" was provided by Mr. M. B. Hall, director of training for the Foxboro Co., Foxboro, Massachusetts.

Throughout his discussion Mr. Hall answered the numerous questions from the audience on air operated controllers. The evening also included a short business meeting, and a nomination slate of new officers was scheduled for the next meeting. The members also agreed upon holding a ladies night in May with arrangements to be completed by Mr. John Hillen, Chairman of the program committee.

—G. A. Rice, Corr.

NEW JERSEY

To fill a need for better working knowledge of what derivative control is and how to use it, a combined afternoon and evening session was held by the New Jersey Section at the Essex House, Newark, on April 5th. Interest in the subject was evidenced by the atendance of 300 members and guests. Two papers were presented, supplemented by three prepared discussions. The afternoon session centered around a paper by V. V. Tivy of The Foxboro Co. entitled "Application of Controllers with Rate Actions." Mr. Tivy discussed what rate action is and how to use it, in a non-mathematical presentation. Curves showing responses of processes to rate action were shown. Analysis of "Signature Curves" to determine suitability of derivative action to processes was emphasized, as a practical means of estab lishing where rate action is beneficial. (J. G Ziegler and N. B. Nichols in their paper have called signature curves by the nam of process reaction curves).

Random variations in measurement sig nals, which electronic engineers call "noise," was outlined. It was interesting to not that some types of industrial measurin devices are becoming sufficiently responsiv so that "noise" is recognizable.

Prepared discussions on Mr. Tivy's pape were presented by R. Clarridge, Taylor In strument Co., L. E. Jewett, Leeds & North rup and A. E. Krogh, Brown Instrumen Div. of Minneapolis-Honeywell.

For the evening session C. B. Moore o Moore Products Co. presented a paper o "Inverse Derivative" which removed muc of the mystery that surrounds this contro action. A major item in his presentatio consisted of a selection chart showing re gions of usefulness of both direct and in verse derivative.

Between sessions The Foxboro Co. provided a demonstration, using a dummy electronic process on which it was possible to synthesize most types of signature curves and show the interaction effects of various settings of proportional band, reset and derivative action. George R. Feeley, Program Committee Chairman of the New Jersey Section planned the details of the meeting and acted as chairman. Harry F. Moore opened the technical session with a brief definition and explanation of rate action. Herbert Close, President, called a short business meeting for the New Jersey members, at which time Sid Baran, Nominating Committee Chairman, presented the list of candidates for Section officers for the coming year.

The next regular meeting on May 3rd will feature an authoritative paper by Mr. H. Zeibolz, of Askania Regulator Company, on "Hydraulic Control Circuits and Their Applications to the Control of Industrial Processes." For the meeting of June 7th, a special demonstration of "Automatic Control Principles" will be presented by Mr. Richard Pond, of Taylor Instrument Companies, at the Engineering Building Auditorium, Rutgers University, New Brunswick, New Jersey.

—W. A. HAGERBAUMER, Corr.

NEW YORK

The March 28th meeting was held at the Hotel Statler and Mr. A. B. Geuder spoke on "A Discussion of Hagan Ring Balance Instruments." This talk was well illustrated with slides showing the available types and various applications.

The April 25th meeting will be a visit to the Columbia University Cyclotron Laboratory at Irving, New York. The May 23rd meeting will be held jointly with the Radio Club of America with Professor B. Weber, of Brooklyn Polytechnic Institute, who will give a paper on Magnetic Amplification.

Mr. A. K. Joecks, Chairman of our 1950 Conference on Temperature Measurement, is now working on the program.

—H. R. KALBFLEISCH, Corr.

NIAGARA FRONTIER

The regular meeting was held on March 28th at The New York State Institute of Applied Arts & Sciences in Buffalo, N. Y. About 35 members attended a dinner, preceding the meeting, in the institute's dining room. An additional ten members arrived later for the meeting.

A short business meeting was held, which included a discussion regarding plans for the 1950 ISA National Convention in Buffalo, led by Mr. M. D. Shriver, Convention Committee Chairman.

President Clarence Boltz then introduced Mr. W. E. Rufieth, application engineer of the Bristol Co., who delivered a very interesting talk on the subject of "Telemetering." Mr. Rufieth's talk was illustrated with projection slides, and covered a description of early models as well as the latest types of telemetering equipment. Many interesting applications of telemetering were described in the talk and the question period which followed.

—W. J. SOMMERS, Corr.

PHILADELPHIA

The March meeting was held Wednesday night, March 16th, at the Bellevue-Stratford Hotel, Mr. Henry P. Adams, Sr., Meteorologist of the Philadelphia Weather Bureau, presented this subject so clearly at our last meeting on March 16, that more than one instrument specialist left with the impression that he was now a junior grade weather forecaster.

Mr. Adams personalized his subject by showing how weather changes our own, our business' and the nation's future. Because of these far reaching effects, governments found weather forecasting necessary. There is a well integrated network of Weather Bureau Stations located throughout the country. Each measures and records wind direction and velocity, barometric pressure, wet and dry bulb temperatures, quality and intensity of rainfall and sunshine. These measured factors are recorded on cylindrical charts to form a daily report that is sent across the country by teletype code. This combined data is plotted on a nation-wide weather map which forms the basis for the weatherman's daily forecast. However, the unexpected can and often does upset the most logical predictions. One hundred eight persons attended the meeting.

—W. E. HARRISON, Corr.

PITTSBURGH

On Monday, March 28th, the Pittsburgh Section had the pleasure of watching a "Visual Explanation of Control Effects." Over 200 members and guests thoroughly enjoyed the presentation by Mr. R. S. Pond of the Taylor Instrument Companies.

The presentation commenced with a story entitled "Two Happy Partners," relating the adventures which befell them when a batch process was expanded and converted into continuous operation. Then, using a sample liquid level installation, control responses were recorded on a giant strip chart as changes were made in throttling range, reset rate, preact time, supply and demand side capacities and process load.

The next meeting will be held on April 25th at the Roosevelt Hotel. Dr. E. L. Harder of Westinghouse Electric Corp. will speak on "The Analog Computer."

—M. M. FROMM, Corr.

ROCHESTER

The March 22nd meeting was held in the Bausch and Lomb Physics Building of the University of Rochester following a dinner meeting in honor of the guest speaker, Prof. P. E. Mohn, Dean of Engineering at the University of Buffalo.

Dean Mohn's talk entitled, "The Flow of Water in Glass Pipes" included motion pictures in which flow in laminar and turbulent patterns was well illustrated. The test apparatus was constructed and photographed at the University of Illinois in 1940 by Dean Mohn. The apparatus consisted of a large glass tank which supplied a glass pipeline. A mixture of benzene and carbon-tetrachloride was introduced into the pipe line in a manner such that small globules were produced. A small area of the flowing stream was highly illuminated and photographed. A great change in pattern was evident as the flow changed from laminar to turbulent at a Reynolds number of about 2500. A very interesting pattern illustrating the effect of water hammer was shown when a discharge valve was closed rapidly.

—EINAR W. JENSEN, Corr.

WAYNE COUNTY

The April meeting was well attended. Two visitors from California, five from Ohio, and a speaker from Massachusetts helped swell the group. Our election resulted in the choosing of the following officers:

President—Mr. R. A. Wright, Metrol Co.
First Vice-President—Mr. B. K. Beecher, Research, Wyandotte Chemical.
Second Vice-President—Mr. Henry Arauz, Brown Instrument Co.
Secretary—Mr. R. J. Karr, Research, Pennsylvania Salt Co.
Treasurer—Mr. R. L. Kimball, Instrument Dept., Pennsylvania Salt Co.

Mr. A. R. Catheron of the Foxboro Co. explained and demonstrated the Foxboro Analog. Simple control problems were introduced and solved, the oscilloscopes showing controller and valve response. The problems were made more complex by introducing the equivalent of lags, etc., and the necessary adjustments simulating sensitivity, reset, and rate response were made, the oscilloscopes again showing action of controller and valve. It was then explained that recorder responses could be used in the analog for determining controller selection and settings.

—JOHN MACPHERSON, Corr.

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TEMPERATURE CONTROL *Continued from page 448*

the most general case of automatic control of temperature. The relation was the relation between the variations:

dQ, heat input to the heating unit per unit of time;
dt, time elapsed; and
$d\theta$, temperature in the heating unit.

This relation, which was used as a basis for Formula 20, was the following:

$$dQ = \mp K_1 dt - K_2 d\theta.$$

In the particular case under review—that of positioning continuous temperature control—coefficient K_1 equals 0 and this relation becomes:

$$dQ = -K_2 d\theta$$

from whence: $K_2 = -\frac{dQ}{d\theta}$

We can therefore see that, in this case, coefficient K_2 corresponds to the variation of heat input per unit of time, or—which is identical—to the opening or closing of the controlled valve, for a given variation $d\theta$ of temperature in the heating unit.

Therefore, an alteration of the amplifying action alters also coefficient K_2; we shall call the latter the coefficient of amplification.

In this controller, the device for adjusting the action of compensating bellows P on the position of pivot O of flapper B has a dial calibrated in throttling range figures. The latter expresses percent temperature changes that result in full travel of the controlled valve from one extreme position to the other (from fully closed to fully open); i.e., in a variation of controlled air pressure from its maximum to its minimum or vice versa.

If the controller's thermometer is calibrated from 50° to 250° (having thus a span of 200°) calibration "1" of the adjusting dial insures full travel of the controlled valve for a 1% temperature change in the heating unit, i.e., a variation of 2°. In other terms, a temperature change of 1° will result in half of full travel of the controlled valve.

With calibration "150" of the adjusting dial set in front of the index mark, this same 200-span controller will give the controlled valve its full travel for a 150% temperature change, i.e. a variation of 300° in the heating unit. This means that a temperature change of 1° will move the controlled valve 1/300 of its full travel.

Thus, a high amplifying action of the controller corresponds to low throttling range calibrations of the adjusting dial, and vice versa.

We can therefore easily establish a relation between the coefficient of amplification K_2 and throttling range calibrations of the adjusting dial.

Let us assume that the controller is set for a temperature midway between its maximum calibration θ_{max} and its minimum calibration θ_{min}. This means that, if calibration "100" of the adjusting dial is set in front of the index mark, the temperature in the heating unit will have to drop from θ_{max} to θ_{min} to move the controlled valve from its maximum closed to its maximum open position.

If we call Q_{min} and Q_{max} the minimum and maximum values of the heat input per unit of time, the integration of equation

$$dQ = -K_2 d\theta$$

between limits Q_{min} and Q_{max} for the left-hand member, θ_{max} and θ_{min} for the right-hand member will give:

$$\int_{Q_{min}}^{Q_{max}} dQ = -K_2 \int_{\theta_{max}}^{\theta_{min}} d\theta$$

from whence:

$$Q_{max} - Q_{min} = -K_2 (\theta_{min} - \theta_{max}) = K_2 (\theta_{max} - \theta_{min})$$

If, instead of calibration "100", any other calibration n of the adjusting dial is set in front of the index mark, the left-hand member of the preceding formula will not be altered. As to the right-hand member, it will have to be multiplied by $n/100$; indeed the temperature change giving the controlled valve its full travel will be in this case:

$$\frac{n}{100} (\theta_{max} - \theta_{min}) \text{ instead of } (\theta_{max} - \theta_{min})$$

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Critical damping resistance	500 ohms.
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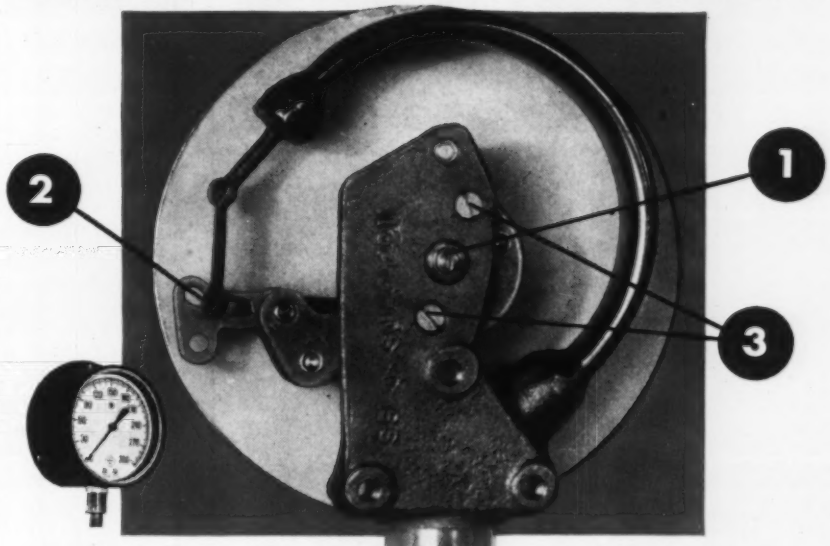

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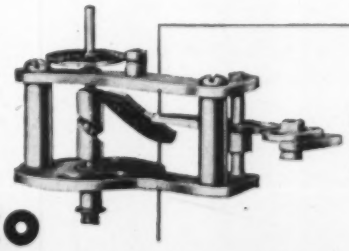

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We can therefore write:

$$Q_{max} - Q_{min} = \frac{n}{100} K_2 (\theta_{max} - \theta_{min})$$

from whence: $K_2 = \frac{100}{n} \frac{(Q_{max} - Q_{min})}{(\theta_{max} - \theta_{min})}$ liters/second

This formula gives high amplification coefficients K_2 for low throttling range calibrations n, and vice versa.

We have outlined the fact that positioning controllers have the inconvenient of not being isothermic. Indeed, they insure a balance between heat input and heat output at temperatures different from one case to another.

In this way, the controlled temperature is never accurately maintained constant. For instance, if balance is restored at a temperature located below the control point, the only way of resetting this temperature would be to open the controlled valve beyond its position of equilibrium; on the other hand, this valve has no reason to open any more as balance is restored for a heat input lower than that required to reach again the control point.

In order to diminish the deviation of balance temperatures from the control point, coefficient K_2 may be increased; this insures full travel of the controlled valve for a small temperature change. It is obvious, on the other hand, that any exaggeration of such adjustments would frequently risk giving the controlled valve its full travel in the event of sudden temperature changes; this valve would then constantly operate under discontinuous control. Therefore, positioning controllers are to be used either in cases where close control is unnecessary or in cases where the fictitious mass of the heating unit is sufficiently high to prevent sudden temperature fluctuations. In this second instance, amplification coefficient K_2 can receive sufficiently high values to insure small deviations of balance temperatures from the control point; the controller is indeed unlikely to operate under discontinuous control as risks of rough temperature changes are minimized.

All other cases—as, for instance, most petroleum refining problems—where accurate control is to be combined with low heat inertia, require the use of positioning plus floating controllers. The latter are equipped with a complementary device which introduces, besides positioning control, a component of floating control depending on time elapsed alone. This is correct as we must recall that floating control suits heating units having low fictitious masses.

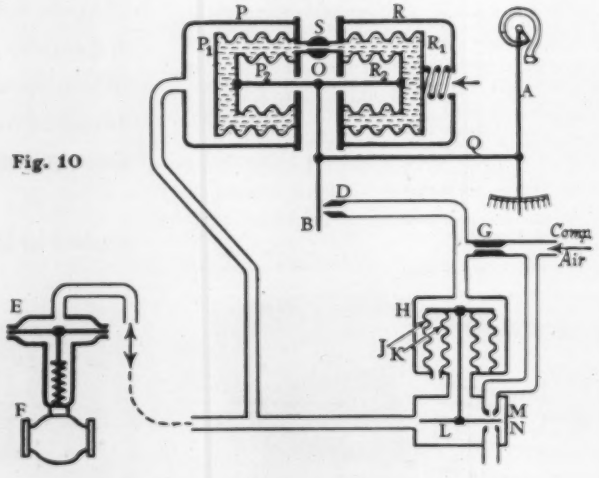

Fig. 10

The positioning plus floating controller, Fig. 10, is similar to that in Fig. 9; it likewise has a compensating bellows P; but spring C is replaced by a second bellows R. Moreover, bellows P and R are each represented by a pair of concentric bellows P_1 and P_2, R_1 and R_2. The space between each pair of bellows if filled with light oil and inner bellows P_2 and R_2 are connected by a rod which carries pivot O of flapper B.

The right-hand surface of outer bellows R_1 is under atmospheric

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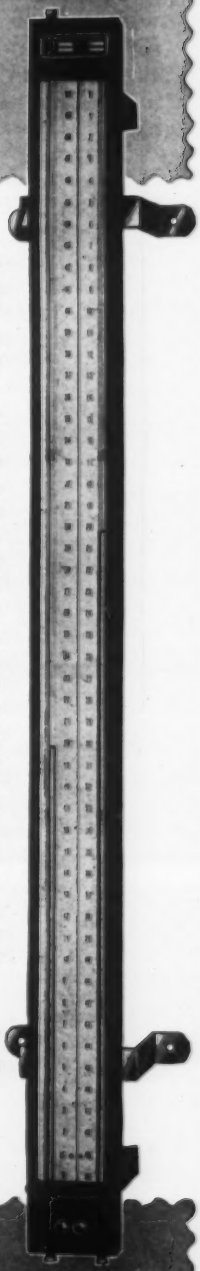

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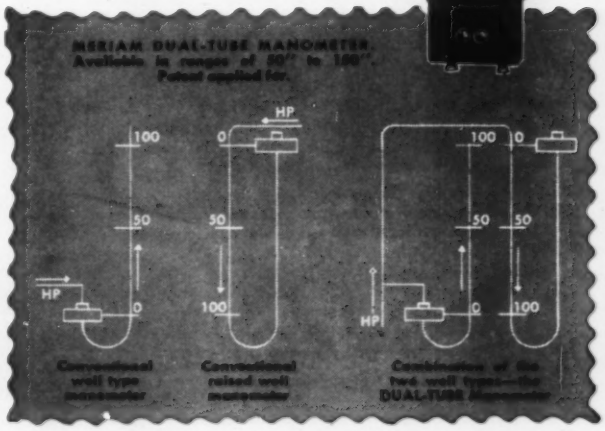

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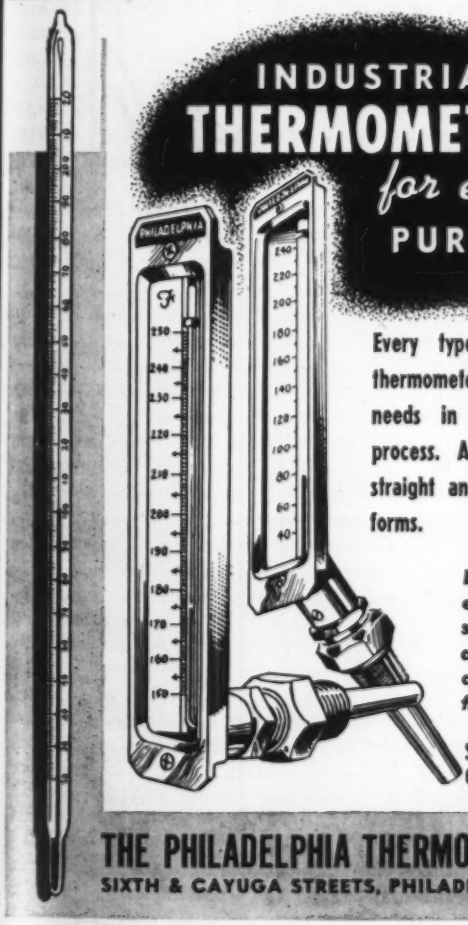

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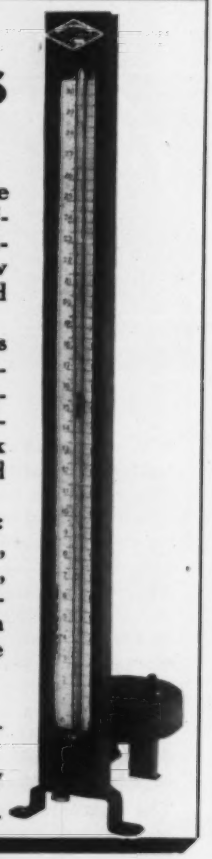

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pressure and is balanced by a spring; the space between bellows R_1 and R_2 is connected to that between bellows P_1 and P_2 through a small tubing throttled by means of a small needle valve S.

To begin with, we shall assume that needle valve S is completely closed. The controller's action will be the same as that of the Fig. 9 controller: positioning control.

As previously described, a deviation of temperature in the heating unit from the control point moves pen A, altering the flow of air through nozzle D. The air pressure on diaphragm E of controlled valve F—and on outer compensating bellows P_1—increases or decreases; valve F gradually closes or opens while bellows P_2 moves to the right or left.

Inner bellows P_2 will follow this motion and move in the same direction as inner bellows R_2 to which it is connected; finally, outer bellows R_1 will also follow the same movement, being assisted by the action of its spring.

In this way, as previously, pivot O of flapper B will move to the right or left; this flapper will therefore move to the left or right, i.e. in a direction opposite to that of its original motion under the action of pen A, and will again become vertical.

As the controlled temperature changes, flapper B will move to the right or left in a way parallel to itself and perpendicular to the rod connecting inner bellows P_2 and R_2; this rod will therefore also move with respect to outer bellows P_1 and R_1 and will consequently take an eccentric position inside these outer bellows. Outer bellows R_1 being subjected to atmospheric pressure the pressure of the oil between it and R_2 will not change; but the oil pressure between bellows P_1 and P_2 *will* change as air pressure exerted on outer bellows P_1 increases or decreases.

If we assume now that needle valve S is open, there will be a flow of oil from the left-hand to the right-hand capacity or vice versa depending on oil pressure between bellows P_1 and P_2 with respect to that between bellows R_1 and R_2. This movement of oil will stop only when both capacities will be under the same pressure.

As oil flows through needle valve S, the volume of the left-hand capacity decreases or increases while that of the right-hand capacity increases or decreases. Therefore, inner bellows P_2 and R_2 move together to the left or right, i.e. in a direction opposite to their motion under positioning control alone. This results, in turn, in a movement to the left or right of pivot O of flapper B; this flapper, instead of remaining vertical, will again become inclined with respect to nozzle D. The flow of air through the latter will again decrease or increase and, therefore, air pressure exerted on diaphragm E of controlled valve F will again increase or decrease. Valve F will thus close or open *more* than it would do under positioning control alone.

This automatic reset action will continue until oil pressures in left-hand and right-hand capacities are equalized. This equality of pressures requires obviously a centered position of both inner bellows P_2 and R_2 inside both outer bellows P_1 and R_1. This condition calls, in turn, for a return of pivot O of flapper B to its initial position, in the middle of the length of outer bellows P_1 and R_1; on the other hand, flapper B can recover its initial position only if pen A does likewise, i.e. only if temperature in the heating unit is again brought to the control point.

The controlled valve will therefore *continue* to close or to open under the action of automatic reset until the temperature in the heating unit is brought back to the control point. The automatic-reset device thus opposes any balance above or below this control point; it prevents "load error" or "droop" and automatically insures constancy of temperature.

The position of needle valve S governs the *speed* or *rate* of automatic reset. When this valve is closed, no oil flows from one capacity to the other: there is no automatic reset at all; the controller operates under positioning control alone. If needle valve S is wide open, the speed or rate of automatic reset is maximal. Of course, an infinite number of adjustments can be made between these two limit positions of the needle valve.

As we have already seen, the temperature in the heating unit is not actually reset to a given control point but rather brought inside a neutral zone, between two limits of control. The width

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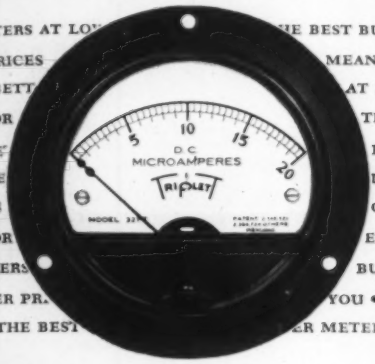

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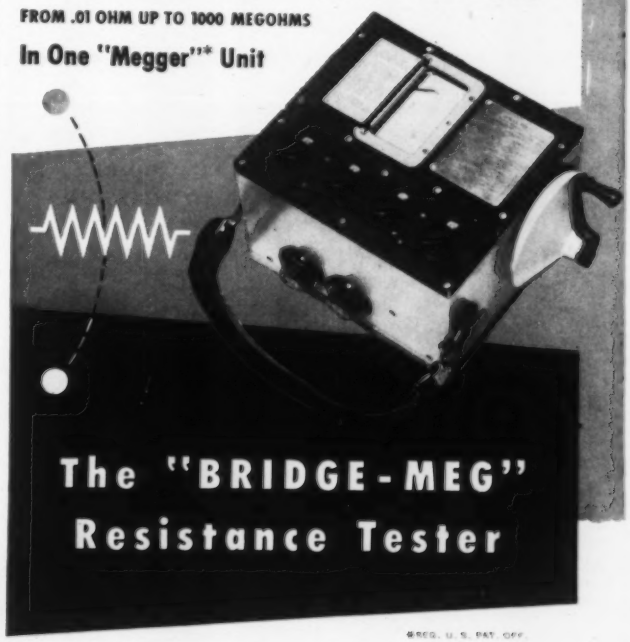

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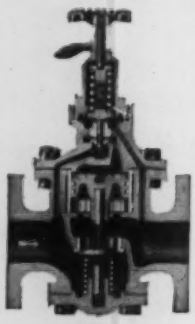

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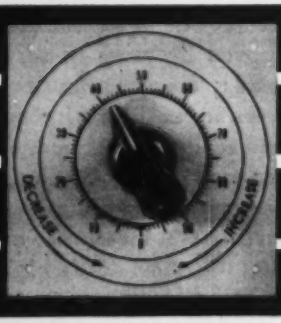

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of this neutral zone is governed by the sensitivity of the controller; it is not adjustable in the type of instruments under review.

Now, let us take the general relation

$$dQ = \mp K_1\, dt - K_2\, d\theta$$

which corresponds to positioning plus floating control and consider the automatic reset action alone. This means that we neglect the throttling action and therefore assume that $K_2 = 0$. The preceding relation becomes

$$dQ = \mp K_1\, dt$$

from whence: $K_1 = \mp dQ/dt$

Coefficient K_1 expresses therefore the rate of change of heat input per unit of time under automatic-reset action alone. It can be also considered as the speed of valve travel under automatic-reset action alone or—which is similar—as the rate of automatic reset toward the control point. We shall call this coefficient, for this reason, the coefficient of automatic reset.

In the described controller, the rate of reset to the control point is not a constant but depends on the difference of oil pressures in left-hand and right-hand capacities, i.e. on the deviation of the controlled temperature from the control point. This speed is therefore maximal when temperature deviation from the control point is maximal; it decreases down to 0 as the temperature approaches this control point.

All our formulae having been established for constant-speed, floating, or positioning-plus-floating controllers, the described variable-speed positioning-plus-floating controller is governed by an equation of the type:

$$dQ = K_1\,(\theta_1 - \theta)\, dt - K_2\, d\theta$$

instead of:

$$dQ = \mp K_1\, dt - K_2\, d\theta.$$

The described controller has therefore, in addition to the knob for setting the control point, two adjusting dials. The first is calibrated in percent temperature changes for full valve travel and is used for adjusting the amplification or throttling range. The second bears marks without any absolute significance; it is attached to needle valve S and serves to adjust the automatic-reset rate. By this means it is possible to adjust the throttling range to suit the amplitude of heated-medium flow fluctuations; while the rate of automatic reset is adjusted to suit the frequency of such fluctuations.

CONCLUSION

Our different formulae link together the fictitious mass of a heating unit, the variations of heated-medium flow and the resulting temperature changes. They can therefore help to select an appropriate type of controller intended to maintain a given constancy of temperature in a given heating unit for given variations of heated-medium flow.

From this standpoint, discontinuous control suits heating units having very large fictitious masses or subjected to very small fluctuations of heated-medium flow. Positioning control is to be used in cases where an accurate constancy of temperature is unnecessary or where the fictitious mass of the heating unit is sufficiently large to cut down the effects of sharp fluctuations of heated-medium flow. Positioning plus floating control allows to insure an accurate constancy of controlled temperature even in heating units having small fictitious masses and subjected to sudden changes of heated-medium flow.

These formulae do not pretend to be rigorously accurate in application and are likely to be altered here and there by dint of practical research. Their main interest is to lead, while starting on the entirely conventional basis of the fictitious mass, to results confirmed by conclusions drawn from routine instrument practice. This justifies giving credence to the theoretical concepts on which our essay is based.

The concept of the fictitious mass can be used to solve other problems than those reviewed in this essay. We have omitted, for the sake of brevity, the case of heat inertia in buildings; but it is easy to consider a building as a heating unit receiving a given heat

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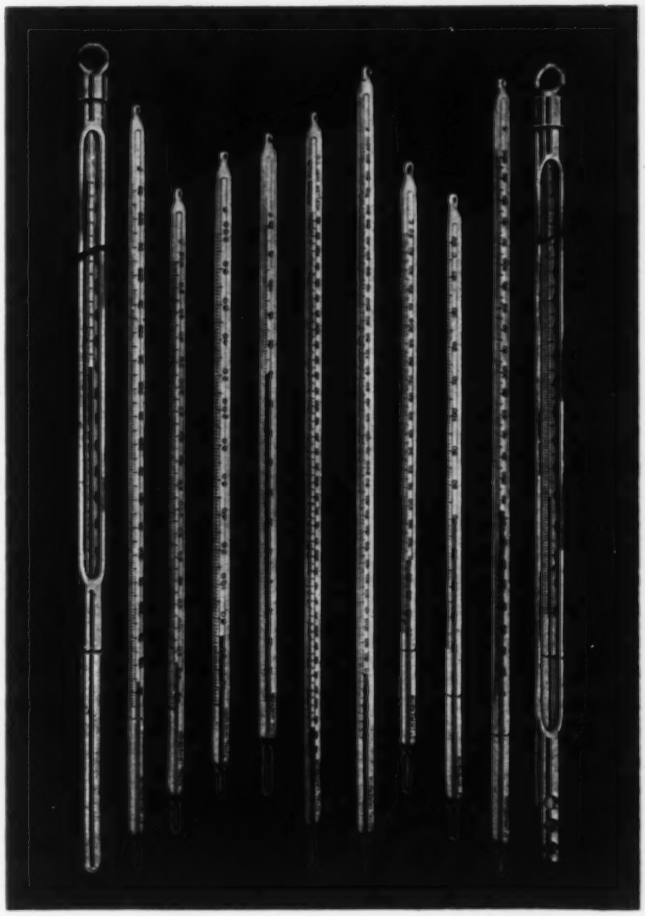

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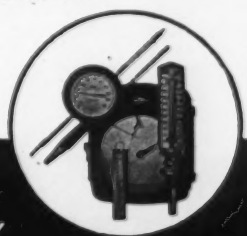

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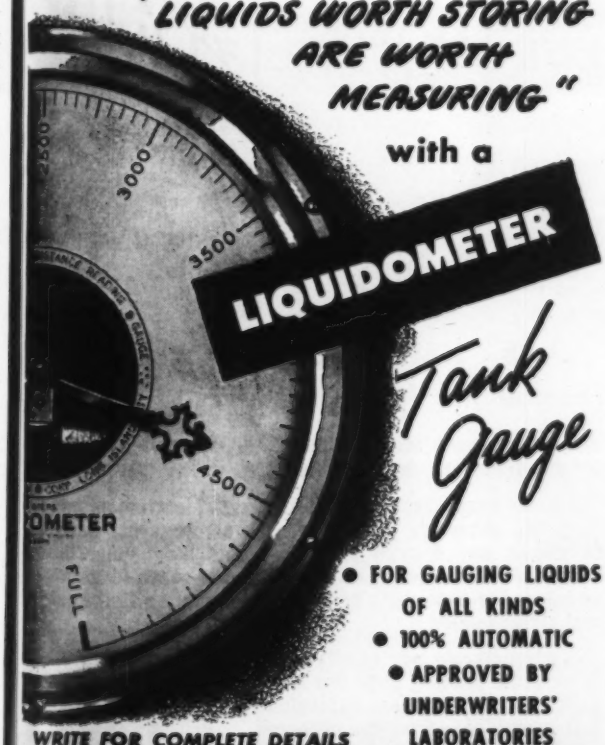

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All this practical research work and the simplified method just mentioned were based on the present essay, the original French text of which was first published in 1942. We trust, therefore, that the concept of the fictitious mass of a heating unit—which has already led to encouraging practical results—will enable a new and large development in automatic temperature control applications.

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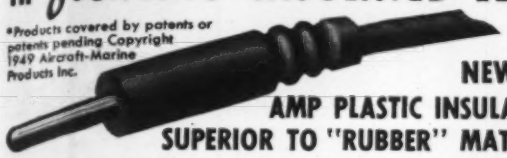

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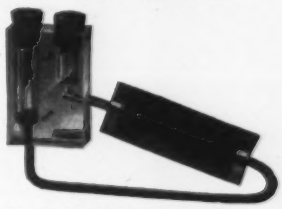

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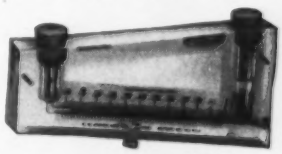

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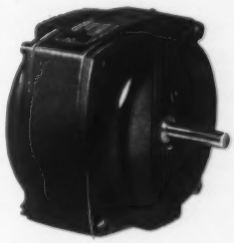

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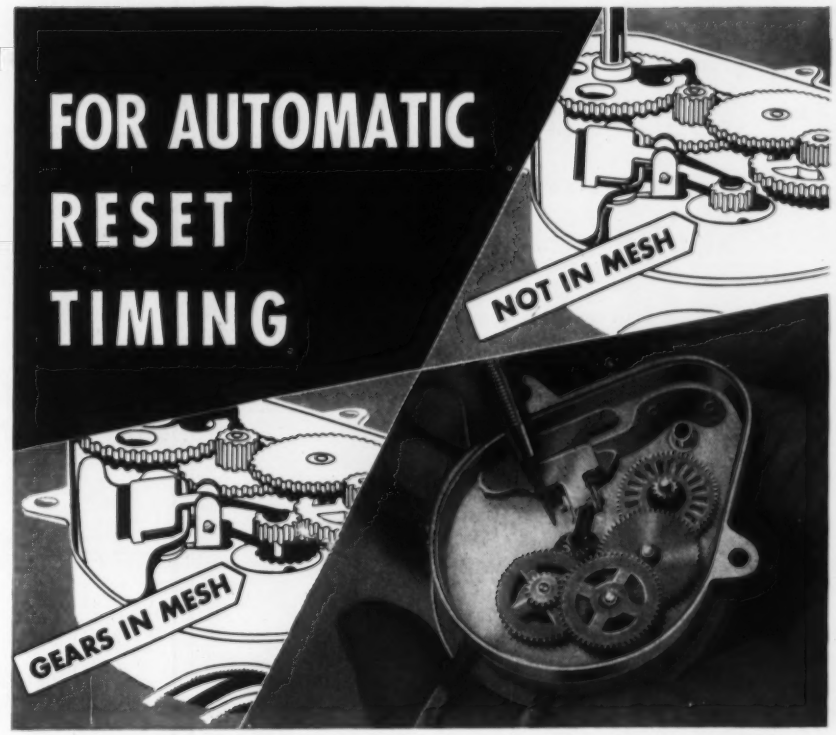

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R-248 MEASURING MICROSCOPES. 26-page Bulletin No. 161—48 describes and illustrates maker's measuring microscopes for laboratory and shop. Includes discussion of measuring microscopes, their selection, and use. Described are: reading microscopes, telemicroscopes, telescopes, filar micrometer microscopes, scale micrometer microscopes, etc. Also included are microscope accessories, micrometer slides, comparators, miscellaneous measuring instruments.—Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill.

R-249 "CEC RECORDINGS." 6-page Vol. 3, No. 1 issue of this house organ presents discussion titled "New Sampling Probe Raises Leak Detector Sensitivity 1000X". Also discusses 600-ft. paper developed for recording oscillographs; automatic high-vacuum bakeout oven, etc.—Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena 4, Calif.

R-250 MULTI-PURPOSE CARRIER. 4-page Folder 44P4 describes and illustrates radio and wireline applications covered by maker's "Type 44" carrier equipment. Shows how these units can be employed for voice, telegraph, telemetering, and control installations. Tabulation details type of operation, transmission speed or band width, number of channels, channel spacing, etc.—Lenkurt Electric Co., Inc., 1118 County Road, San Carlos, Calif.

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R-253 "THE CAPACITOR." 16-page Vol. 14, No. 3 issue of this house organ presents article titled "Taking Complete Receiver Performance Data," and contains "Trading Post" section, a free market-place for buyers, sellers and swappers. —Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

R-254 AN-TYPE CONNECTORS. 2-page bulletin describes and illustrates maker's redesigned "Vibrationproof" series of AN-type connectors which has added features of: radio-shielding, pressurizing, moisture-proofing.—Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif.

R-255 "THE GENERAL RADIO EXPERIMENTER." 8-page Vol. 23, No. 10 issue of this house organ presents article titled "A New Bridge

for Impedance Measurements at Frequencies Between 50 Kilocycles and 5 Megacycles. Also included is article on counter tubes; miscellany section.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

R-256 RADIO TERMINAL CONNECTORS. 4-page Bulletin RTC-1 describes and illustrates maker's "RTC" series connectors, a new development to meet need for quick disconnect on radio chassis, wall or rack mounting installations. Standard and special models are discussed.—Cannon Electric Development Co., 3209 Humboldt St., Los Angeles, Calif.

R-257 TENSILE TESTERS. 4-page bulletin describes and illustrates maker's "Model TT-B" tensile testing equipment for accurately measuring and recording load-elongation properties under tensile loading; hysteresis; relaxation effects. Included are design features, design principles, drive mechanisms, etc.—Instron Engineering Corp., 8 Hancock St., Quincy 71, Mass.

R-258 OSCILLOSCOPE RECORDING CAMERA. 4-page bulletin describes and illustrates maker's "Model D" oscilloscope recording camera, said to be ideally suited for study of transients involving use of oscilloscope; have extensive application in science, medicine, industry. Construction, operation, adaptability, flexibility, etc. discussed.—Frederick P. Warrick, 8666 Grandville, Detroit 28, Mich.

R-259 MAGNETIC AMPLIFIERS. 32-page Bulletin No. VT-2000 presents discussion of magnetic amplifier circuits, characteristics, applications. Glossary of terms is included.—Vickers Electric Division, Vickers Inc., 1815 Locust Street, St. Louis 3, Mo.

R-260 ENCLOSED SWITCHES. 2-page Data Sheet No. 49 describes and illustrates maker's "BAF1—2RN-LH" and "BAF1—2RN—RH" die cast aluminum enclosed switches. Features, characteristics, etc. are discussed.—Micro Switch, Freeport, Ill.

R-261 ELECTRONIC PNEUMATIC MECHANICAL INSTRUMENTATION. 32-page Vol. 3, No. 6 issue of this house organ presents articles titled "Instruments for Producing Modern Pharmaceuticals," "Quality Control in Tin Plate Production," "Innovations in Varnish Kettle Control," and others. Illustrations and diagrams are used throughout.—Minneapolis-Honeywell Regulator Co., Brown Instrument Div., Wayne and Roberts Avenues, Philadelphia 44, Penna.

R-262 INSTRUMENT PANELBOARDS. 12-page Bulletin No. 125-5-47 describes and illustrates new trends in cabinet design, control cubicles, instrument panelboards, standard panel units and accessories. Included are maker's typical installations, and re-design methods.—Falstrom Co., Falstrom Court, Passaic, N. J.

R-263 CONTROL CENTERS. 4-page bulletin describes and illustrates maker's new concept in design development for control centers. Features, construction, etc. discussed.—Falstrom Co., Falstrom Court, Passaic, N. J.

R-264 COMBUSTION TUBES. 4-page booklet describes and illustrates maker's high temperature tubes for analysis by combustion, pyrometry, and high temperature heat treatment. Also included is description and illustrations of maker's pure oxide ware for process and research.—Morganite Inc., 3302 48th Ave., Long Island City 1, N. Y.

R-265 "MODERN PRECISION." 8-page Vol. 3, No. 4 issue of this house organ contains articles concerning metals, process industries, ceramics,

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